Observations-based Guidance for Short-term Cloud Ceiling Forecasts at Kennedy Space Center: Development and Implementation

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• Data Analysis  
• Equation Development  
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Task Background

• Cloud ceiling critical element for Shuttle landings, but challenging to forecast, even in the short-term (0-6 hours)
• AMU was tasked to develop an objective method to help improve ceiling forecasts at SLF
• AMU task methodology based on two studies in literature:
  – Vislocky and Fritsch (1997 WAF): Surface data from surrounding stations
  – Hilliker and Fritsch (1999 JAM): Added sounding data
• Weather element to be predicted (predictand): Probability of occurrence of ceiling categories in Shuttle FR
  – Less than 5000 ft RTLS
  – Less than 8000 ft EOM
  – Less than 10 000 ft Nav Aid Degradation
Data Analysis and Preparation

• Surface stations in boxes used in development - other stations eliminated due to short period of record (POR) or missing data
• POR: 1978 – 1997
• Quality control done to remove obvious outliers
• Stratified data into cool season (October – March) and warm season (April – September) sets
• Created dependent and independent data sets
• Prepared binary predictands, determined and prepared predictors
Equation Development

- Equations developed using cool season dependent data set
- Predict probability of 3 Shuttle FR ceiling categories for 1-, 2-, and 3-hour lead times every hour of day
- Observations-Based Equations
  - Observations from 5 stations used as potential predictors
  - Predictors chosen through forward stepwise regression
  - Average 4 – 5 predictors per equation
- Persistence Climatology Equations
  - Benchmark against which observations-based forecasts compared
  - Uses observation of predictand at initial time, climatological term of predictand at valid time
- All equations developed with linear regression model

\[ 3 \text{ predictands} \times 3 \text{ lead-times} \times 24 \text{ hours} \times 2 \text{ methods} = 432 \text{ Equations} \]
Results

- Probability forecasts made using each technique
- Mean Square Error (MSE): average of squared differences between binary observation and probability forecast
  \[ \text{MSE} = \frac{1}{n} \sum_{i=1}^{n} (f_i - o_i)^2 \]
- MSE (E) used to calculate a skill (S) score
  \[ S = \left( \frac{E_{ob} - E_{pc}}{E_0 - E_{pc}} \right) \times 100 \]
  where \( S \equiv \% \text{ Improvement} \)
  - \( E_{ob} \equiv \) Observations-based MSE
  - \( E_{pc} \equiv \) Persistence Climatology MSE
  - \( E_0 \equiv \) Perfect Forecast (0)
- Positive \( S \): observations-based forecast is an improvement over persistence climatology
Results

- S from forecasts using independent data
- < 10 000’: Values positive, increase with lead time
- < 8000’: Scores lower, on average, than < 10 000’
- < 5000’: 1 negative value (-0.6) at 2000 UTC, all others positive and lower than other 2 categories
- Hypothesis test indicated improvement significant beyond 99% confidence
Results

- Probability of Detection (POD) and False Alarm Rate (FAR) calculated using standard contingency tables
- Yes/No forecast threshold at 0.5 (50%) probability
- Average values over 24 forecast equations per category/lead time
- PODs much higher than FARs
- Decrease in POD and increase in FAR with lead time

<table>
<thead>
<tr>
<th>Lead Time by Category</th>
<th>POD</th>
<th>FAR</th>
</tr>
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<tbody>
<tr>
<td>&lt;10 000 ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Hour</td>
<td>0.83</td>
<td>0.16</td>
</tr>
<tr>
<td>2-Hour</td>
<td>0.73</td>
<td>0.21</td>
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<tr>
<td>3-Hour</td>
<td>0.67</td>
<td>0.25</td>
</tr>
<tr>
<td>&lt;8000 ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Hour</td>
<td>0.83</td>
<td>0.17</td>
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<tr>
<td>2-Hour</td>
<td>0.70</td>
<td>0.23</td>
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<tr>
<td>3-Hour</td>
<td>0.63</td>
<td>0.27</td>
</tr>
<tr>
<td>&lt;5000 ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Hour</td>
<td>0.80</td>
<td>0.18</td>
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<td>2-Hour</td>
<td>0.65</td>
<td>0.24</td>
</tr>
<tr>
<td>3-Hour</td>
<td>0.54</td>
<td>0.27</td>
</tr>
</tbody>
</table>
SMG Operational Implementation

- AWIPS local application using Tcl/Tk and Perl
- Equation coefficients stored as comma separated variable files to allow easy updating
- Retrieves surface observations data from AWIPS netCDF files
- Automatically updates each hour with new prediction
- Allows manual input of observations for forecaster training
Summary and Conclusions

• Developed set of probability forecast equations for occurrence of ceilings < 10,000 ft, < 8000 ft, < 5000 ft at 1-, 2-, 3-hour lead times each hour of day in cool season (October – March)

• Observations-based equations showed significant skill over persistence climatology beyond 99% confidence, good PODs and FARs

• Positive results prompted SMG to develop AWIPS graphical display of probability forecasts for use in Shuttle landing operations

• Equations, with other observations/forecaster experience, can be used to improve ceiling forecasts for Shuttle landings at KSC

• For a copy of the final report describing details of the development, contact lambert.winifred@ensco.com