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

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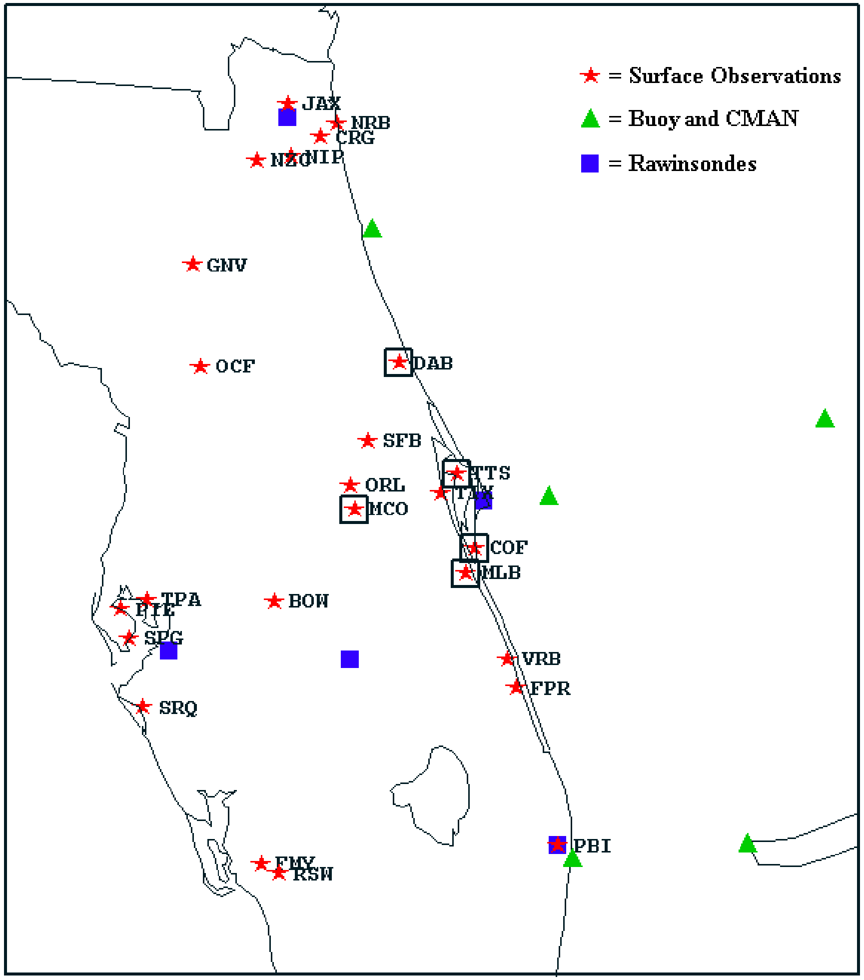
- Task Background
- Data Analysis
- Equation Development
- Results
- Operational Display
- Summary and Conclusions

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



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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 predictands x 3 lead-times x 24 hours x 2 methods = ***432 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

$$S = [(E_{ob} - E_{pc})/(E_0 - E_{pc})] \times 100$$

where $S \equiv$ % Improvement

$E_{ob} \equiv$ Observations-based MSE

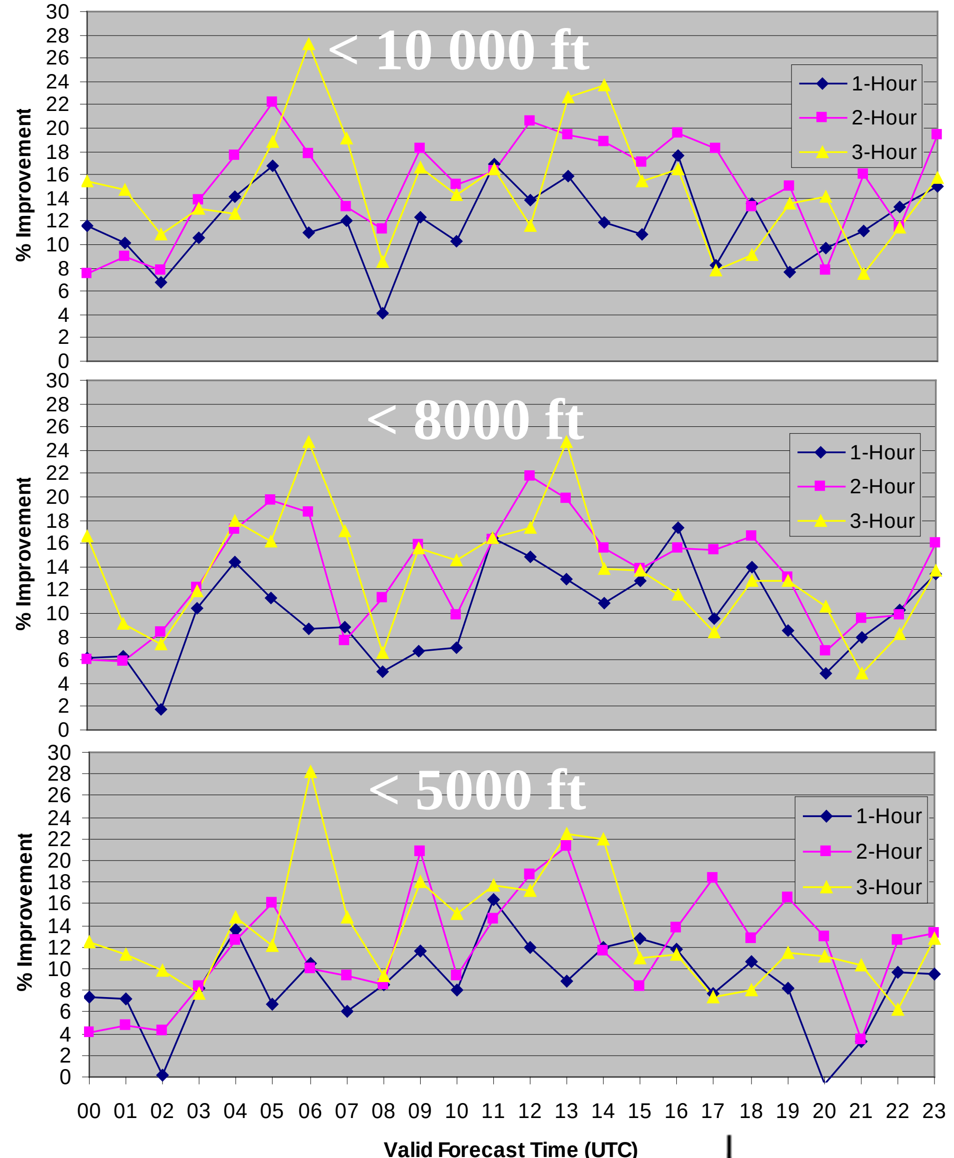
$E_{pc} \equiv$ Persistence Climatology MSE

$E_0 \equiv$ 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



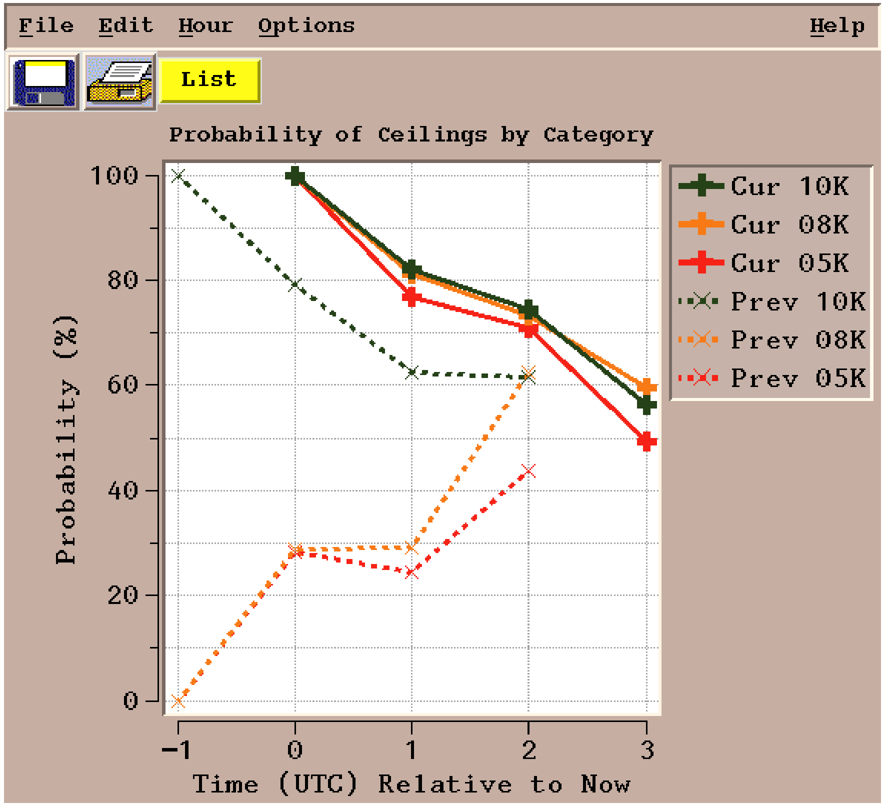
Results

- 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

Lead Time by Category	POD	FAR
<10 000 ft		
1-Hour	0.83	0.16
2-Hour	0.73	0.21
3-Hour	0.67	0.25
<8000 ft		
1-Hour	0.83	0.17
2-Hour	0.70	0.23
3-Hour	0.63	0.27
<5000 ft		
1-Hour	0.80	0.18
2-Hour	0.65	0.24
3-Hour	0.54	0.27

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



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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