UPDATE TO THE OBJECTIVE LIGHTNING PROBABILITY FORECAST TOOL IN USE AT CAPE CANAVERAL AIR FORCE STATION, FLORIDA

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BACKGROUND

The 45th Weather Squadron (45 WS) forecasters at Cape Canaveral Air Force Station (CCAFS) include the probability of lightning occurrence in their 24-Hour and Weekly Planning Forecasts, briefed daily at 0700 EDT (1100 UTC). This forecast is used to plan for daily operations at Kennedy Space Center (KSC) and CCAFS.

Prior to development of the Objective Lightning Probability tool, this forecast was based on a subjective analysis of model and observational data, and output from the Neumann-Pfeffer Thunderstorm Index (NPTI; Neumann 1971), an algorithm developed specifically for KSC/CCAFS. However, several studies showed that one-day persistence outperformed the NPTI by ~10%.

The 45 WS forecasters required increased reliability and objectivity in the lightning probability forecast and requested that the Applied Meteorology Unit (AMU) build a tool that would meet those needs. Such a tool was developed by the AMU in Phase I of this work (Lambert and Wheeler, 2005). This poster describes results from Phase II in which the tool was updated to increase its skill, accuracy, and reliability (Lambert 2007).

PHASE I SUMMARY

The AMU developed five equations, one for each warm season month May–September, using data from the 15-year period 1989–2003. These equations output the probability of lightning occurrence for the day using data available to the forecasters prior to the 0700 EDT weather briefing. The Phase I equations showed

- An ability to distinguish between lightning/non-lightning days,
- Good reliability, accuracy, and skill,
- 31-53% improvement over persistence, and
- 48% improvement over NPTI

Because of their good performance, they were transitioned to operations in the form of a user-friendly graphical user interface (GUI).

PHASE II GOALS:

The Phase II work had two goals. The first was to modify the data set and determine if it would improve equation performance. These modifications were to

- Increase the period of record (POR) from 15 to 17 years (1989–2005),
- Change the valid area for lightning occurrence, and
- Try new formulations for three important Phase I predictors:
  - Test new smoothing parameters for the daily climatological probability,
  - Use the CCAFS 1000 UTC sounding to help determine the flow regime, and
  - Determine the mean RH layer most correlated to lightning occurrence.

The second goal was to create a GUI on the 45 WS operational weather display system. The Phase I GUI required forecasters to input data manually. This used critical time needed to forecast other parameters and increased the likelihood of entering an incorrect value.

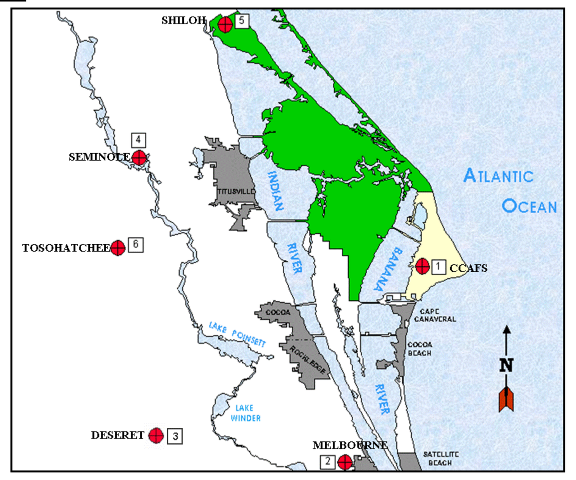
DATA SOURCES (PHASE I and II)

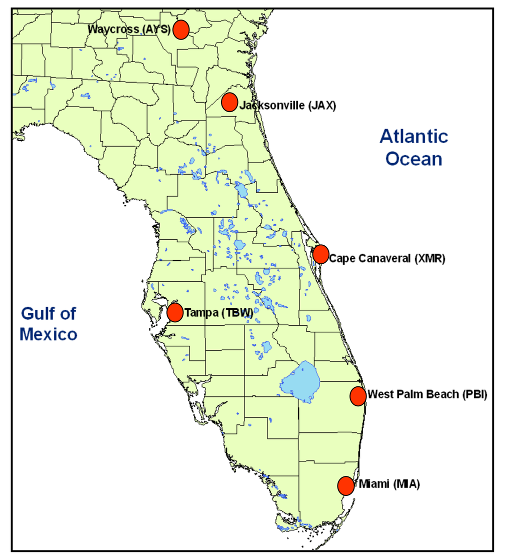
Cloud-to-Ground Lightning Surveillance System (CGLSS)

CGLSS is a network of six sensors surrounding the KSC/CCAFS area that provide

- Date and time,
- Latitude and longitude, and
- Strength and polarity of CG strikes.

These data were used to determine lightning occurrence for each day. Only one CG was required.





1200 UTC soundings at Miami, Tampa, and Jacksonville

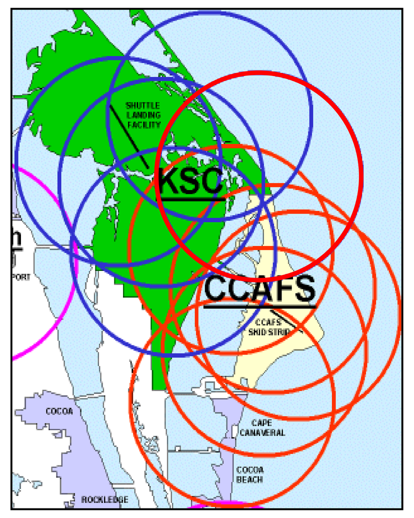
Following Lericos et al. (2002), the mean wind directions in the 1000–700 mb layers at these stations were used to determine the flow regime for each day.

1000 UTC CCAFS sounding

Eleven parameters from this sounding were used as candidate predictors. The mean wind in the 1000–700 mb layer was used to determine the flow regime in Phase II.

PHASE II: PREDICTOR MODIFICATIONS

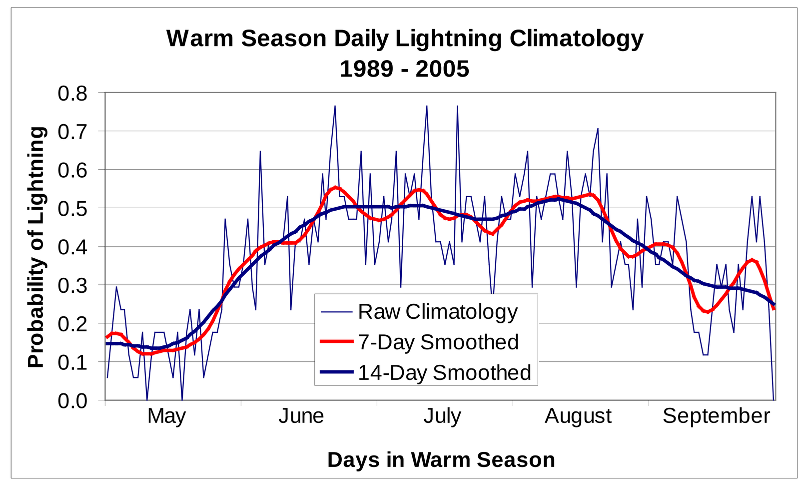
New Valid Area for Lightning Occurrence



The forecasts are for areas within 5 n mi radius circles on KSC/CCAFS (blue and red circles). In Phase I, the valid area for lightning occurrence was a rectangle around all circles.

The 45 WS requested the valid area include only the circles on KSC/CCAFS. If the distance between a CG strike and the center of any circle was ≤ 5 n mi, that strike was considered to be in the valid area.

Change Gaussian Smoother Parameters for Daily Climatology



The daily climatology is the number of lightning days for each date divided by the number of POR years.

A Gaussian smoother was used to eliminate the noise:

- Phase I: ± 7 days, scale factor = 3 days.
- Phase II: ± 14-day scale factor = 7 days.

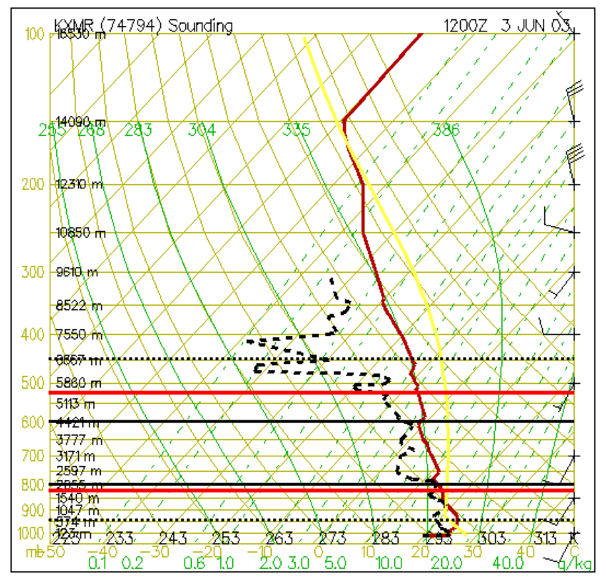
The 14-day curve is likely more representative of a long-term daily climatology.

Flow Regime Discriminator

Lericos et al. (2002) defined six distinct flow regimes. In Phase I, a flow regime was not defined on 44% of the days in the POR.

The 1000 UTC CCAFS sounding was used to determine the flow regime for these days, reducing the number of days in 'Other' and 'Missing' by 70%.

Flow Regimes	*# of Days in POR* Before	After	*Lightning Prob (%)* Before	After
SW-1: Ridge S of MFL	301	301	62	62
SW-2: Ridge btwn MFL and TBW	256	**606**	72	57
SE-1: Ridge btwn TBW and JAX	318	**438**	51	32
SE-2: Ridge N of JAX	248	248	26	26
NW: Northwest flow over FL	100	**307**	43	32
NE: Northeast flow over FL	114	**317**	18	11
Other: Unclassified regime	1077	**326**	44	35
Missing	187	**58**	–	–



Optimal RH Layer in 1000 UTC CCAFS Sounding

The mean 800–600 mb layer RH was a predictor in NPTI and in following studies with no rigorous attempts to test other layers.

An iterative technique was used to find the mean RH layer that most correlated with lightning by calculating:

- The mean RH for layers in 25-mb increments between 950–450mb, then
- Their correlation to lightning occurrence.

The optimal layer was found to be 825–525 mb.

PHASE II: STATISTICS

The data were stratified into 14-year development and 3-year verification data sets. For each warm season day, three random years were chosen, i.e. the verification set contained

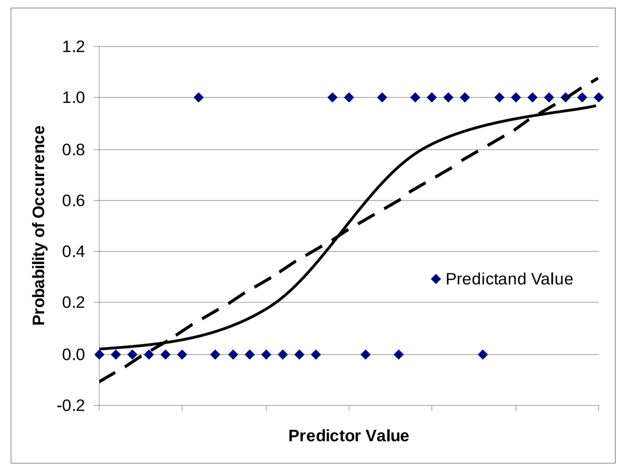
1 May 1999/1989/2001, 2 May 1993/2000/1998, •••, 30 September 1991/1993/2002

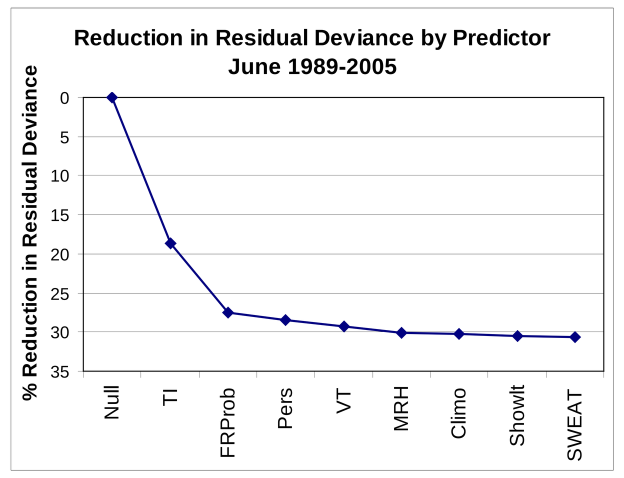
The remaining years became the development data set. This method reduced the likelihood that any unusual convective seasons would bias the results.

Logistic regression was used because

- It always outputs values between 0 and 1,
- And allows for non-linear changes in probability as predictor values exceed a threshold.

$$y = \frac{e^{(b_0 + b_1 x_1 + \ldots + b_k x_k)}}{1 + e^{(b_0 + b_1 x_1 + \ldots + b_k x_k)}}$$





14 candidate predictors used for equation development, all readily available to the 45 WS forecasters.

Final predictors chosen for each equation were those that reduced the residual deviance by ≥ 0.5%.

The five equations each had 4 to 5 predictors.

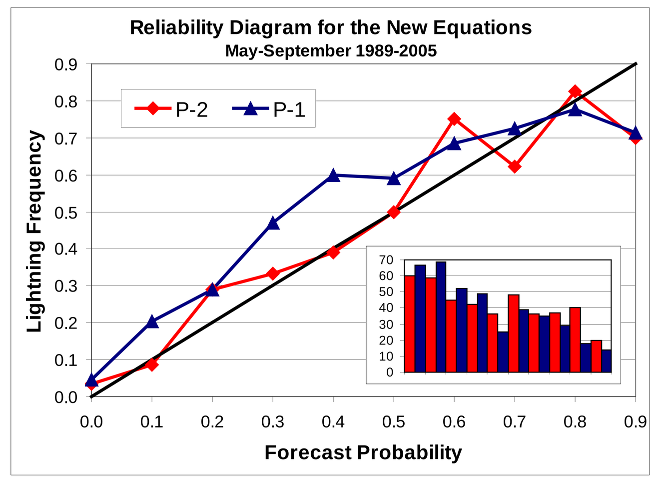
PHASE II: PERFORMANCE

Brier Skill Score

Measures equation performance against other forecast methods in terms of percent improvement or degradation.

The Phase II equations outperformed Phase I by 8% for the full warm season.

Phase II Performance Improvement in %						
Method	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***All***
Persistence	28	41	37	47	41	40
Daily Climo	23	25	24	24	26	25
Monthly Climo	29	27	34	30	25	29
Flow Regime	16	12	11	18	18	15
Phase-1 Eqns	**0.2**	**5**	**19**	**-0.8**	**12**	**8**



Reliability

Shows the degree of over- or under-forecasting at discrete forecast probability values.

Phase I and II equations tend to under-forecast lightning; e.g., when the forecast was 20%, lightning occurred 30% of the time.

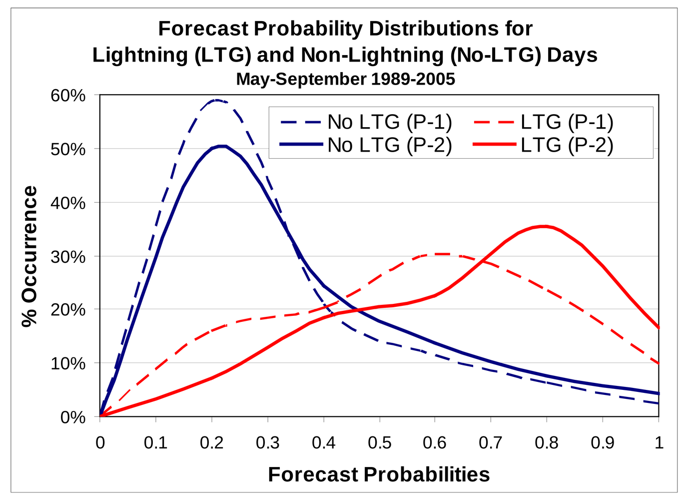
Overall: Phase I bias = -5.9%; Phase II bias = -0.4%.
Phase II equations reduced the bias by over 5%.

Lightning / Non-Lightning Day Distributions

Distributions of forecast probabilities for lightning and non-lightning days show how the equations distinguish between them.

The two equation sets had similar performance for non-lightning days.

The Phase II equations distinguished lightning days better than Phase I.



AUTOMATION

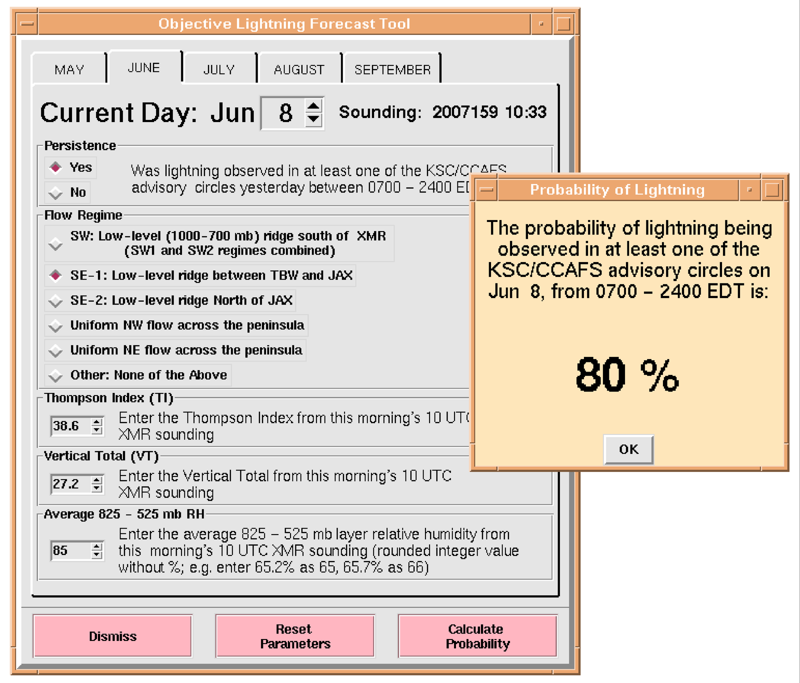
The Phase II equations were transitioned into 45 WS operations in May 2007.

They were made available through a GUI on the Meteorological Interactive Data Display System (MIDDS).

The GUI automatically accesses the date and appropriate sounding parameters for each equation from the 1000 UTC CCAFS sounding.

Forecasters choose 'Yes' or 'No' for persistence and a flow regime for the day.

The MIDDS GUI (right) is similar in form and function to the Phase I GUI, which made the transition easier for the forecasters.



FUTURE WORK: PHASE III

The work in Phase III is driven by the daily climatology curve and has three parts:

- Add October data to capture the spin-down in lightning days at the end of the season,
- Calculate a new 14-day smoothed daily climatology, and then
- Create equations for the progression of the daily climatology instead of each month:

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