Update to the Lightning Probability Forecast Equations at KSC / CCAFS, Florida

Winnie Lambert

NASA Applied Meteorology Unit / ENSCO, Inc. / Cape Canaveral Air Force Station, Florida

William P. Roeder

USAF 45th Weather Squadron / Patrick Air Force Base, Florida

Outline

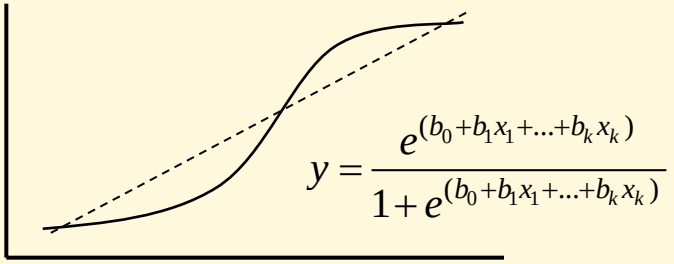
- Overview
- Phase I Summary
- Phase II Goal
- Modifications
- Phase II Tool
  - Predictors
  - Performance
  - Automation
- Future Work and Summary

Overview

- 45 WS provides lightning probability for the day/week
  - Daily Weather Briefing at 7:00 am local time
  - Used for general daily Range operations planning
  - Used model/obs and Neumann-Pfeffer Thunderstorm Index (NPTI)
- Phase I Objective Lightning Forecast Tool
  - Probability of lightning occurrence May–September
  - 48% better skill than NPTI, 40% than persistence
  - Good reliability, accuracy measures, and skill scores
  - Transitioned to operations before 2005 lightning season
- Phase II
  - Modify Phase I predictors to improve performance
  - 8% better skill than Phase I ➡ 56% better skill than NPTI
  - Create Graphical User Interface (GUI) on operational system

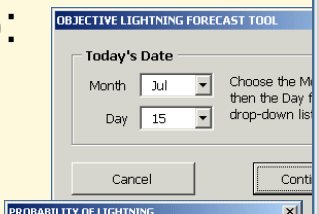
Phase I Summary

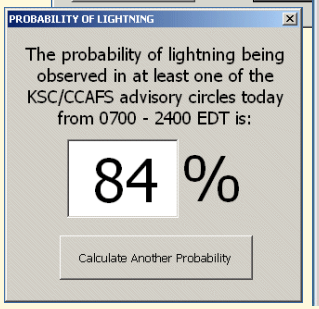
- 5 equations output probability of CG occurrence
  - One equation for each month
  - Logistic regression

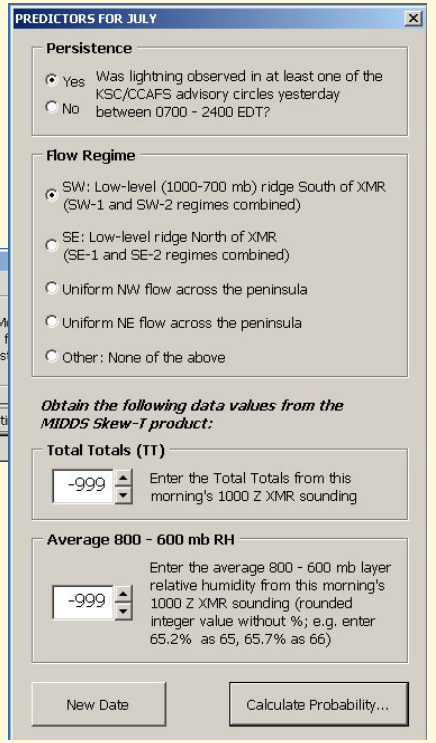


- Each equation had 5-6 predictors
  - Common to all 5 equations:
    Daily climatology, flow regime, 1-day persistence
  - Common to 4 equations (Jun – Sep):
    Mean RH in 800–600 mb layer

- Created PC-based GUI to interface with complex equations





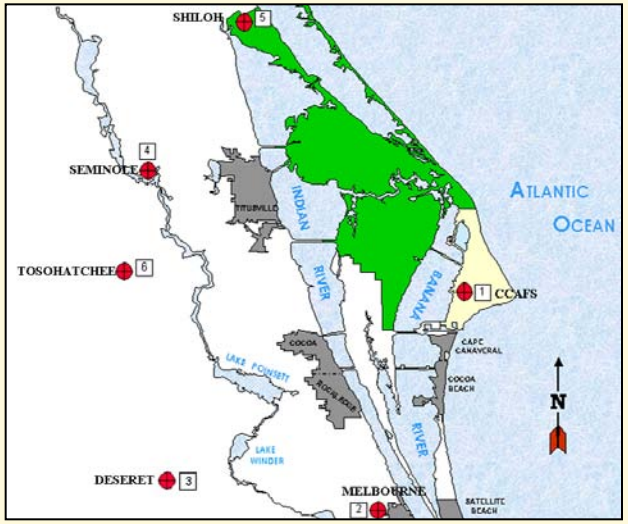


Phase II Goal

- Modify Phase I tool to improve performance
- Two components:
  - Predictor Modifications
    - Increased from 15 to 17 warm seasons (1989 – 2005)
    - New valid area for CG occurrence
    - New smoothing function for daily climatology
    - Changed calculation of flow regime
    - Determined optimal RH layer
  - Automated GUI in 45 WS operational data display system

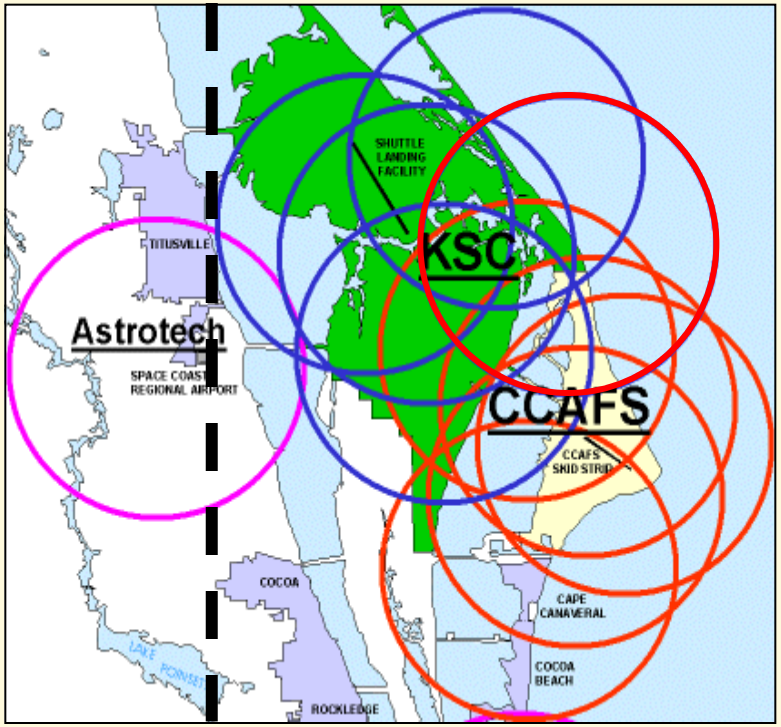
Data Sources

- Cloud-to-Ground Lightning Surveillance System (CGLSS) ground truth for CG occurrence
- Florida 1200 UTC soundings
  - Flow regimes
  - Low-level wind dir at MFL – TBW – JAX
- CCAFS (XMR) 1000 UTC sounding
  - Data used for 7:00 am briefing
  - 11 parameters (e.g. LI, KI, etc.)
  - Flow regime in Phase II



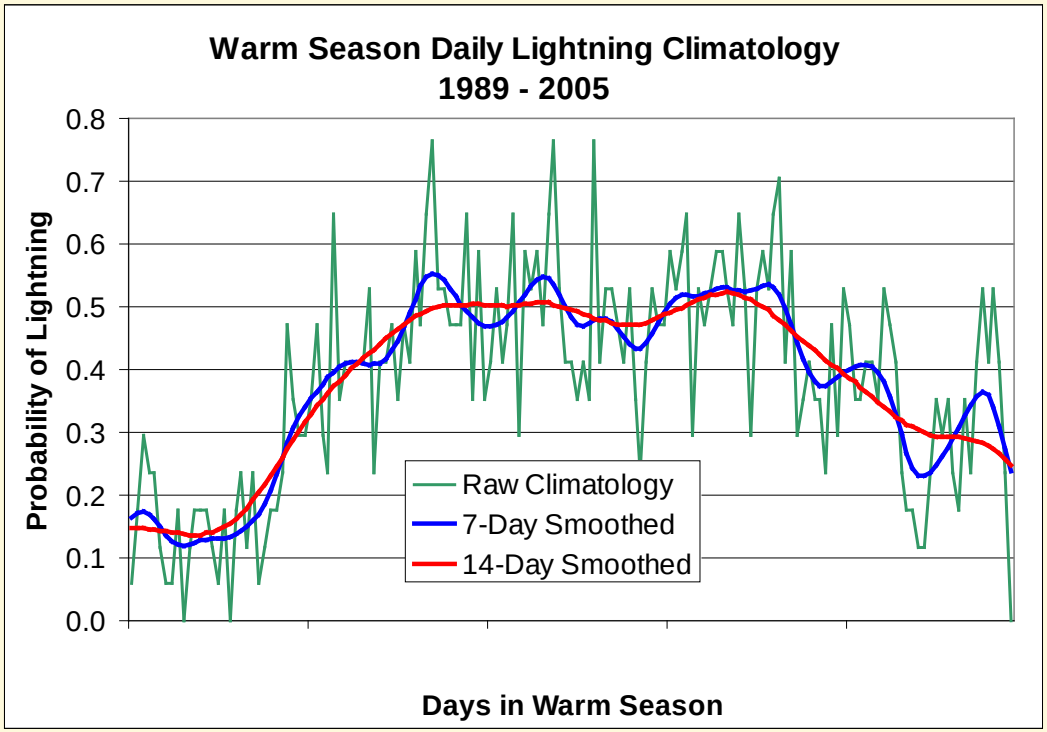
Modifications
Valid Area

- Previous valid area defined by rectangle surrounding all 5 n mi warning circles
- 45 WS planning forecast is for KSC (blue) and CCAFS (red) circles
- Modification: only consider CG within KSC/CCAFS 5 n mi circles
- 1 CG = lightning day



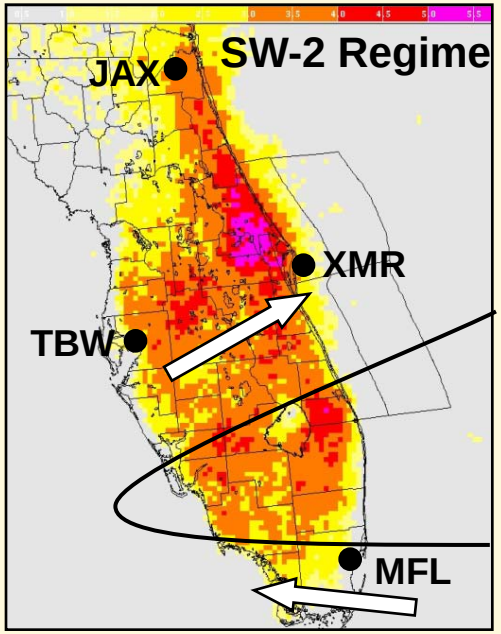
Modifications
Daily Climatology

- # of CG days for each date divided by # years (green curve)
- Smoothing technique: Center-weight Gaussian
  - Phase I (blue curve):
    ±7 days, scale = 3 days
  - Phase II (red curve):
    ±14 days, scale = 7 days



Modifications
Flow Regime

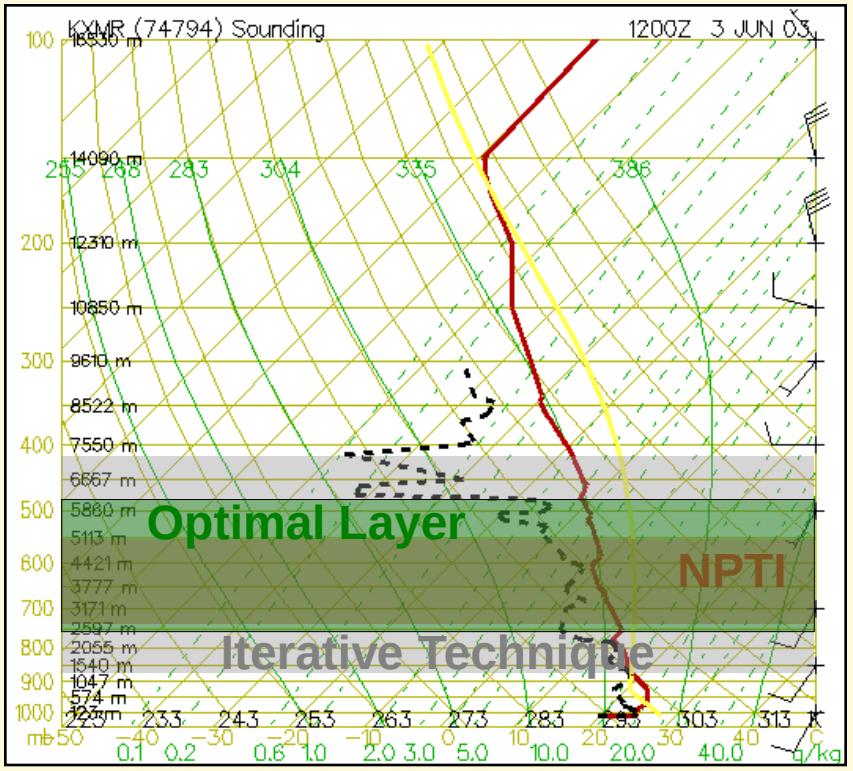
- FSU study: identified six flow regimes determined by:
  - Average 1000–700 mb wind direction
  - 1200 UTC MFL– TBW – JAX
- No flow regime for 42% of days in Phase I
- With XMR 1000 UTC sounding
  - Reduced days in 'Other' and 'Missing' by over **70%**
  - Increased number of days in SW, SE, NE and NW regimes



Flow Regimes	*# of Days* *Before*	*After*
SW-1	301	301
SW-2	256	**606**
SE-1	318	**438**
SE-2	248	248
NW	100	**307**
NE	114	**317**
Other	1077	**326**
Missing	187	**58**

Modifications
Optimal Mid-Level RH Layer

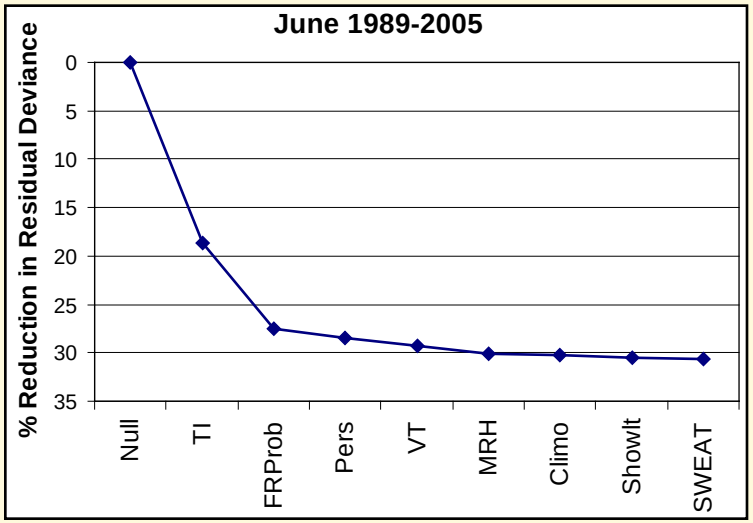
- 800 – 600 mb layer-mean RH used as a predictor in NPTI
- Modification: Find mean RH layer most correlated with lightning occurrence
- Iterative technique
  - Bottom: 950 mb; Top: 450 mb
  - Calculate correlation of each layer to lightning occurrence
- Optimal layer: 825 – 525 mb
  - 1 value for season
  - Monthly values similar



1000 UTC 3 June 2003
CCAFS Sounding

Phase II Equations

- Development data: 14 yrs
  Verification data: 3 yrs
- 14 candidate predictors
- 5 logistic regression equations
- Chose predictors that made > 0.5% reduction in variance

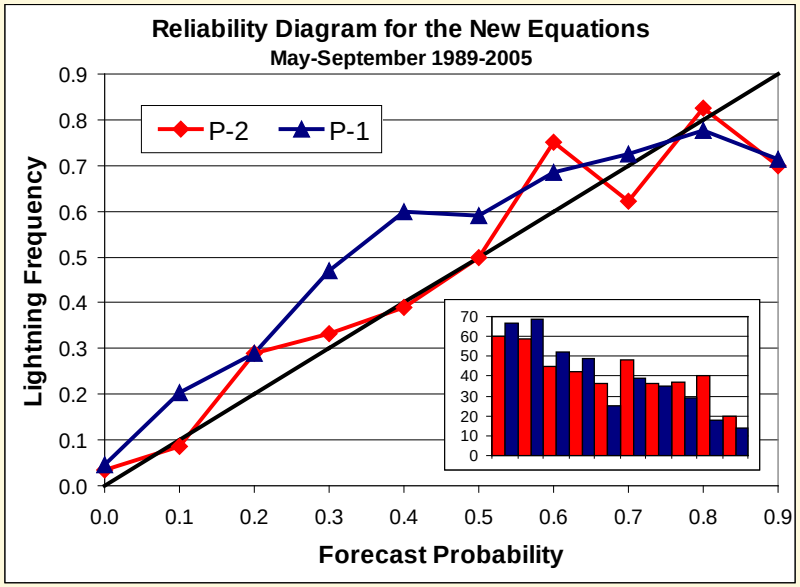


Predictors for Each Month in Rank Order				
May	***June***	***July***	***August***	***September***
K-Index	Thompson Index	Thompson Index	Thompson Index	825–525 mb MRH
Flow Regime	Flow Regime	Flow Regime	Flow Regime	Flow Regime
Vertical Totals	Persistence	Total Totals	Daily Climatology	Persistence
Daily Climatology	Vertical Totals	Persistence	825–525 mb MRH	Vertical Totals
Persistence	825–525 mb MRH		Vertical Totals	Daily Climatology

Performance

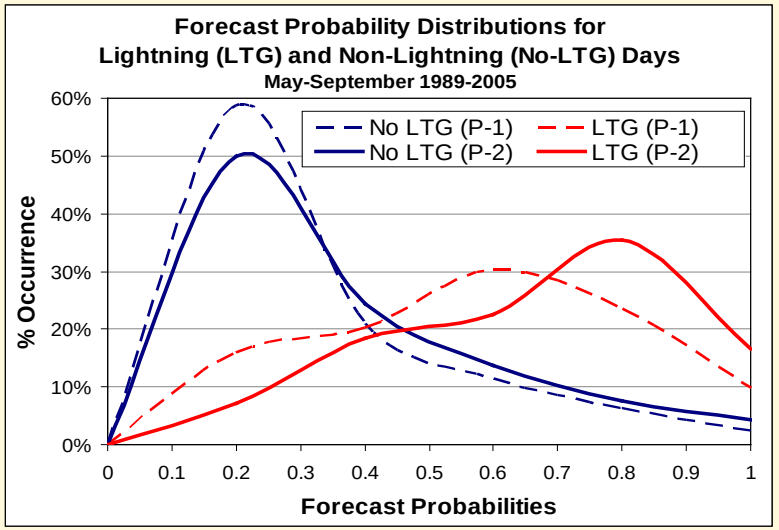
- Four tests using 3-yr verification set
- Brier Skill Score
  - Phase II improved skill over other methods
  - Overall **8%** improved skill over Phase 1, **56%** over NPTI
- Reliability Diagram
  - Black line: perfect reliability
  - Phase I and II have "under-forecast" bias
    - Phase I: -5.9%
    - Phase II: -0.4%
  - Phase II more reliable

% Improvement over Forecast Methods						
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**



Performance

- Lightning/non-lightning day distributions
  - Phase I and II distinguish non-lightning days well
  - Phase II better at distinguishing lightning days

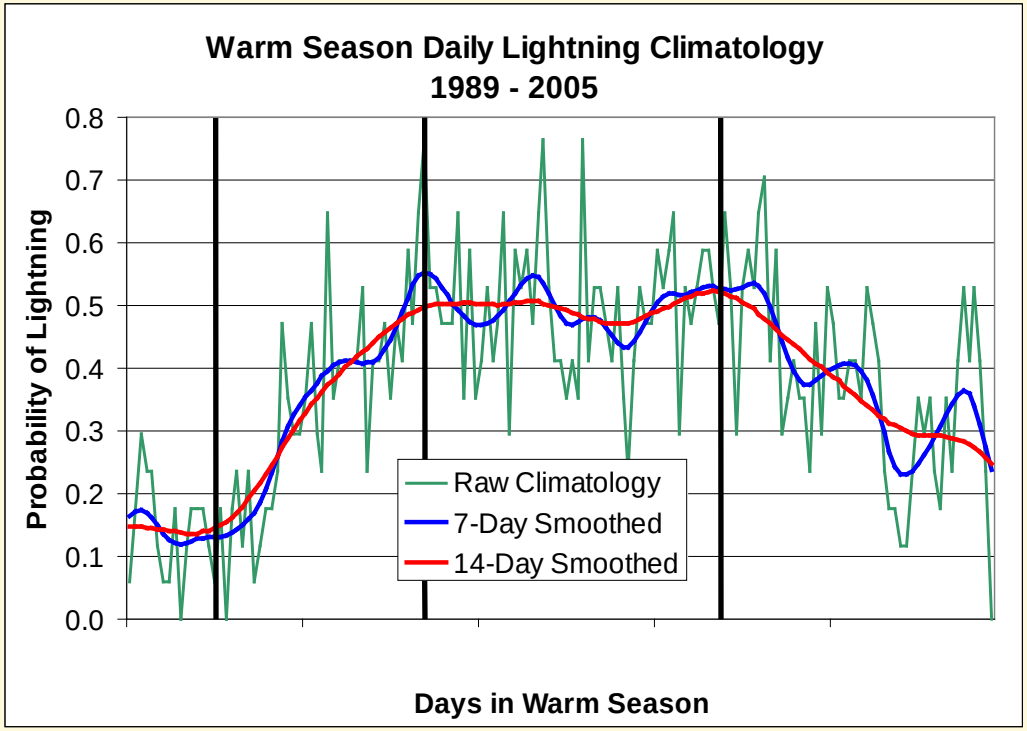


Contingency Table Statistics Updated (P-2) and Phase 1 tools (P-1)			
Statistic	***P-2 (0.47)***	***1-Day Persistence***	***P-1 (0.35)***
POD	0.68	0.62	0.66
FAR	0.21	0.23	0.23
HR	0.74	0.71	0.73
CSI	0.52	0.46	0.50
HSS	0.47	0.40	0.44
KSS	0.47	0.39	0.44

- Contingency table statistics
  - Yes/No cutoff 0.47 for Phase II, 0.35 for Phase I
  - Both Phases better than persistence
  - Phase II scores show best accuracy and skill

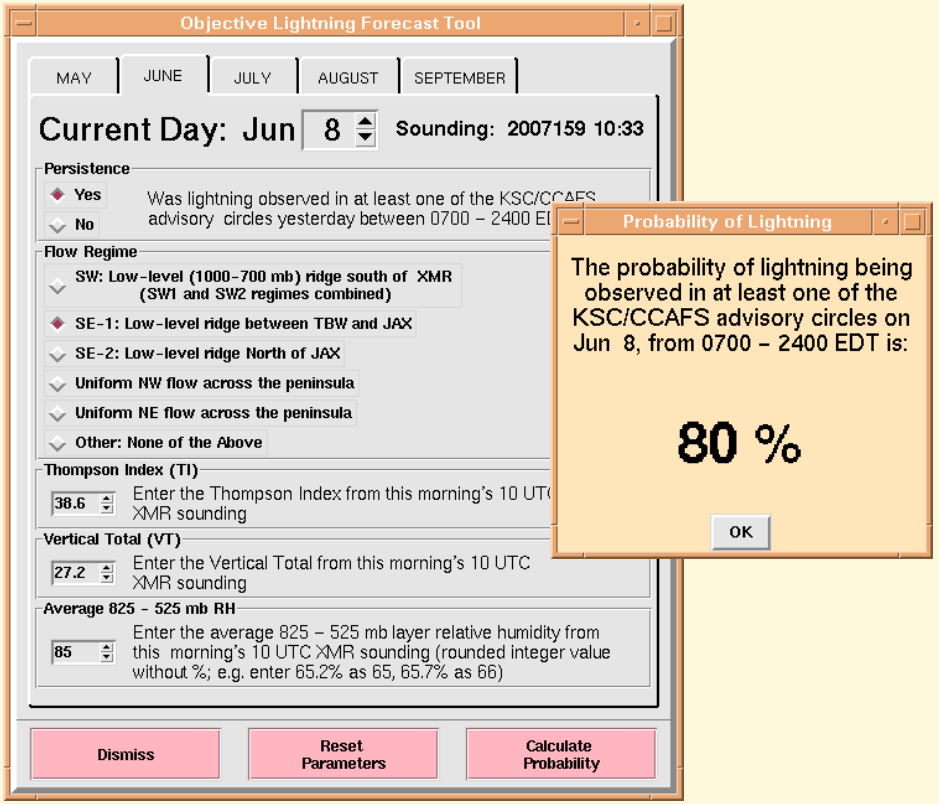
Future Work

- Extend warm season to include October
- Create equations by progression of daily climatology
- 4 or 5 ‘sub-seasons’ dependent on October climatology
  - Early–Mid May: pre-lightning
  - Mid May–Late June: transition / spin-up
  - Late June–Early August: core lightning season
  - Early August–September: transition / spin-down
  - October: ???



Summary

- Phase II equations outperformed Phase I
- Transitioned for 2007 lightning season
  - Automated GUI in McIDAS ingest and display system
  - Date and sounding values input automatically
  - Forecaster inputs flow regime, persistence
- Provides “first-guess” probability for the day
- Forecasters use this, other data sources, experience to make timed forecasts



(GUI developed by Mr. Paul Wahner of CSR)