Objective Lightning Probability Forecast Tool
Phase II

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Outline

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

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
- Subjective analysis of model and observational data
- AMU-developed Objective Lightning Forecast Tool
  - Provide probability of lightning occurrence May–September
  - Accessed through GUI
- 45 WS requested an update to the tool:
  - Modify certain predictors and possibly improve performance
  - Create automated tool

Phase I Summary

- Pre-Phase I: Neumann-Pfeffer Thunderstorm Index (NPTI)
  - Developed over 30 years ago, tuned to KSC/CCAFS area
  - Official objective lightning forecasting tool
- NPTI performance worse than 1-day persistence
- Forecasters requested new lightning forecast tool
- New tool showed
  - 48% improvement over NPTI; 31-53% over persistence
  - Good reliability, accuracy measures, and skill scores
  - Ability to distinguish between lightning/non-lightning days
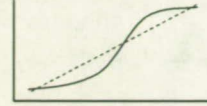- Transitioned to operations before 2005 lightning season

Phase I Summary

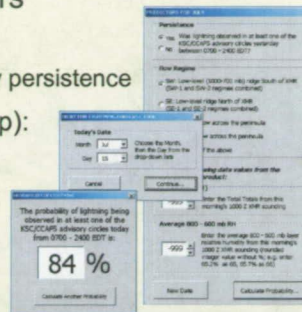- 5 equations output probability of CG occurrence
  - One equation for each month
  - Logistic regression: $y = \dfrac{e^{(b_0 + b_1 x_1 + \ldots + b_k x_k)}}{1 + e^{(b_0 + b_1 x_1 + \ldots + b_k x_k)}}$
- Each equation had 5-6 predictors
  - Common to all 5 equations:
    Daily climatology, flow regime, 1-day persistence
  - Common to 4 equations (Jun – Sep):
    Mean RH in 800–600 mb layer
- Created GUI to interface with complex equations


Phase II Goal

- 45 WS Request
  - Try new formulations of certain predictors
  - Develop an automated tool
- Predictor Modifications
  - Increased POR from 15 to 17 warm seasons (1989 – 2005)
  - New valid area for CG occurrence
  - Used new smoothing function for daily climatology
  - Changed calculation of flow regime
  - Determined optimal RH layer
- Automated Tool
  - Developed in MIDDS by P. Wahner of CSR
  - GUI format similar to previous Excel tool

Data Sources

- Cloud-to-Ground Lightning
  Surveillance System (CGLSS)
  - Ground truth
  - Climatology

- CCAFS (XMR) 1000 UTC sounding
  - Data used for 7:00 am briefing
  - 11 parameters (e.g. LI, KI, etc.)
  - Flow regime in Phase II

- Florida 1200 UTC soundings
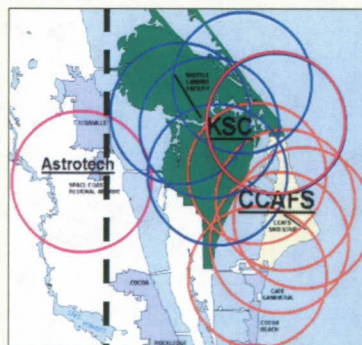 - Flow regimes
  - Low-level wind dir at MIA – TBW – JAX
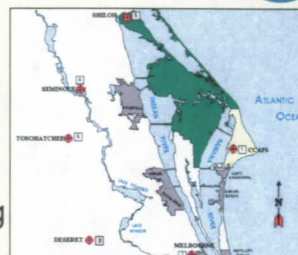
Modifications
Valid Area

- Previous valid area defined
  by rectangle surrounding all
  5 n mi warning circles

- 45 WS planning forecast is
  for KSC/CCAFS circles

- Modification: only use CG
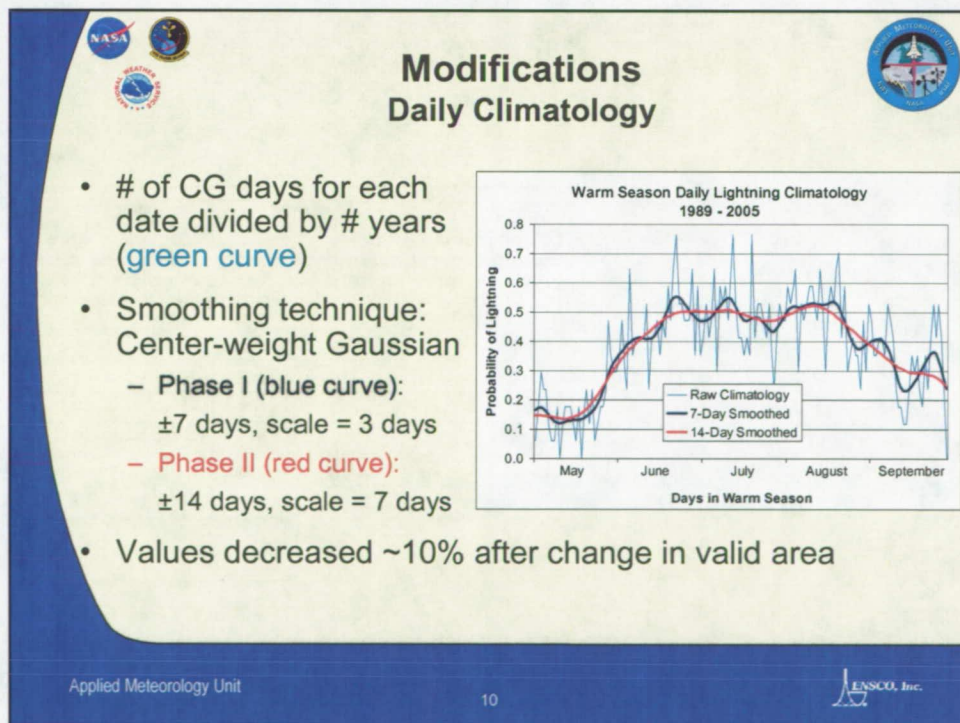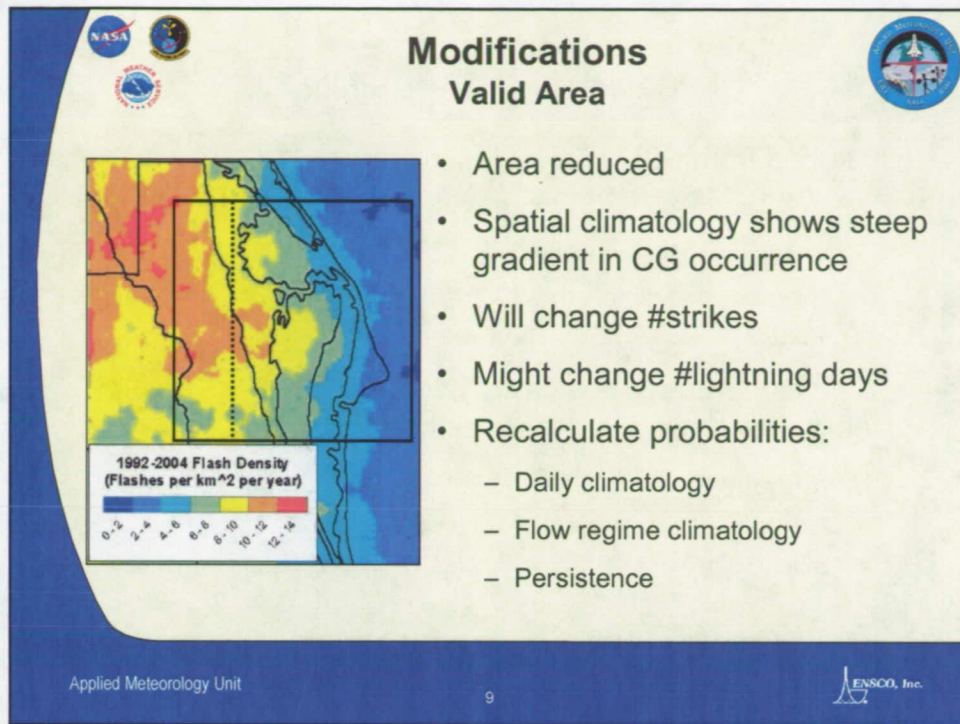 strikes within KSC/CCAFS
  5 n mi circles

Modifications
Valid Area

1992-2004 Flash Density
(Flashes per km^2 per year)

0-2 2-4 4-6 6-8 8-10 10-12 12-14

- Area reduced
- Spatial climatology shows steep gradient in CG occurrence
- Will change #strikes
- Might change #lightning days
- Recalculate probabilities:
  - Daily climatology
  - Flow regime climatology
  - Persistence

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

Warm Season Daily Lightning Climatology 1989 - 2005

Probability of Lightning

May   June   July   August   September

Days in Warm Season

Raw Climatology
7-Day Smoothed
14-Day Smoothed

- Values decreased ~10% after change in valid area

Modifications
Flow Regime Probability

- Method from FSU study: identified six distinct flow regimes

- Flow regime determined by:
  - Average wind direction in 1000–700 mb
  - 1200 UTC MIA – TBW – JAX

- Lightning frequencies calculated for each flow regime in each month

- Modification
  - ISSUE: no flow regime 42% of days
  - SOLUTION: Used XMR 1000 UTC sounding as discriminator

SW-2 Regime
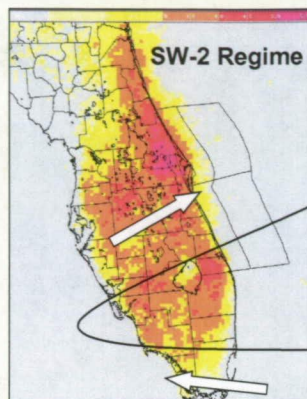
Modifications
Flow Regime Probability

- Using XMR sounding:
  - Reduced days in 'Other' and 'Missing' by over **70%**
  - Increased number of days in SW-2, SE-1, NE and NW

- New values are ~10% lower than Phase I

Flow Regimes	# of Days		Lightning Prob (%)	
	Before	After	Before	After
SW-1	301	301	62	62
SW-2	256	606	72	57
SE-1	318	438	51	32
SE-2	248	248	26	26
NW	100	307	43	32
NE	114	317	18	11
Other	1077	326	44	35
Missing	187	58	–	–

Modifications
Optimal Mid-Level RH Layer

- Mean 800 – 600 mb 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
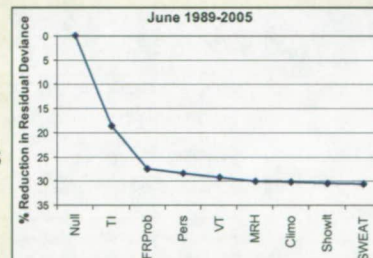- Optimal layer: 825 – 525 mb
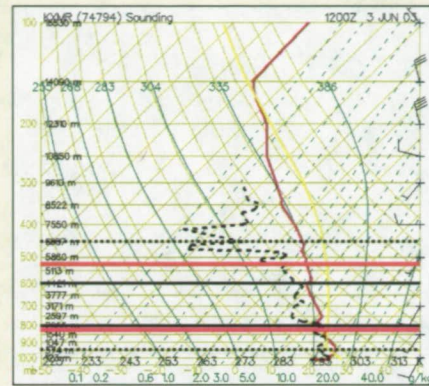
1000 UTC 3 June 2003
CCAFS Sounding

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%** improvement 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%

% 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

Reliability Diagram for the New Equations
May-September 1989-2005
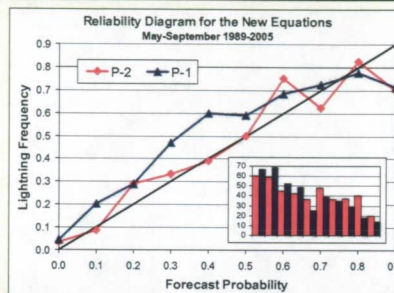
Performance

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

Forecast Probability Distributions for
Lightning (LTG) and Non-Lightning (No-LTG) Days
May-September 1989-2005

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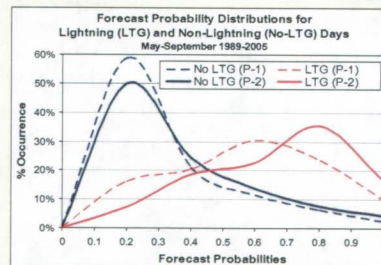
- Contingency table statistics
  - Yes/No cutoff 0.47 for Phase II, 0.35 for Phase I
  - Both Phases better than persistence
  - Phase II scores show best accuracy and skill

Automation

- Equations available through MIDDS GUI
  - Developed by Paul Wahner of CSR
  - Accesses date and parameters from the 1000 UTC XMR sounding.
  - Forecasters choose 'Yes'/'No' for persistence and a flow regime for the day.
- The MIDDS GUI similar to the Phase I GUI

Summary and Future Work

- Phase II equations performed better than Phase I
- Transitioned for 2007 lightning season
- Phase III:
  - Extend forecast to include October
  - Create equations based on daily climatology instead of month

Warm Season Daily Lightning Climatology 1989 - 2005

AMU Website: http://science.ksc.nasa.gov/amu