Diagnosis of Operational Model Track Forecast Error for Hurricane Ike (2008)

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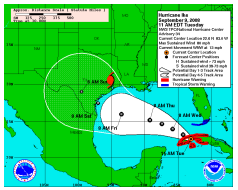
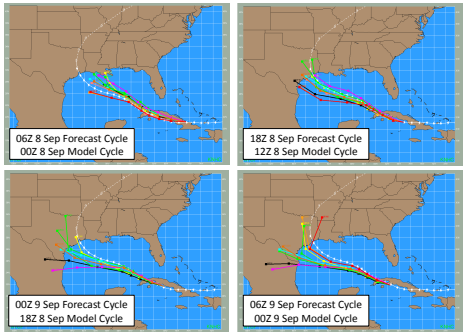
1. Motivation

NHC official track forecast error for Ike increased substantially on 9–10 September 2008

Average error of NHC 72-h forecasts issued on 9 Sep was 38% higher than the average NHC 96-h forecast error from 8 Sep



On 8–9 September all of the track model guidance shifted toward the south and west to the left of the eventual track of Ike (white line)

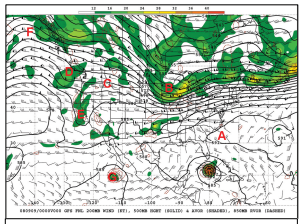


Emergency managers and other users were making critical decisions in this pre-watch time frame (e.g., executing bus contracts for evacuations) when the forecast error increased

Research Questions

Q1: What were the critical synoptic-scale features that influenced the track of Ike?
Q2: What were the sources of initial condition sensitivity in the numerical models?

2. Synoptic Overview and Operational Model Evaluation

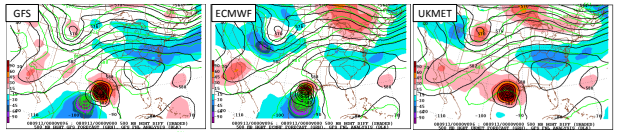


GFS FNL Analysis of 850-hPa rel. vort. (dotted red), 500-hPa height (black) and abs. vort. (shaded), and 200-hPa wind (barbs, kt), valid at 00 UTC 9 September 2008

GFS FNL Analysis at 00 UTC 9 Sep showed several synoptic features potentially important to Ike's track:

A: Subtropical ridge north of Ike
B: Upper Mississippi Valley shortwave
C: Shortwave ridge over the Rockies
D: Shortwave trough over Pacific Northwest
E: Shortwave trough over California coast
F: Longwave ridge south of Alaska
G: Tropical Storm Lowell southwest of Baja

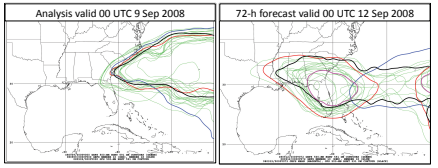
Deterministic Models



96-h 500-hPa height forecasts (green) from the 00 UTC 9 Sep. 2008 cycle from the GFS, ECMWF and UKMET compared with GFS FNL analysis (black). Shading shows height difference (forecast-analysis), with warm (cool) colors showing forecast heights too high (low).

- Subtropical ridge north of Ike displaced too far south/west relative to the analysis in all three models
- Models too weak with California shortwave
- Ike moved well south of the observed best track in the GFS and ECMWF and was unable to gain enough latitude to recurve
- Ike sheared apart and became a shallow feature in the UKMET

GEFS Ensembles



- NCEP GEFS ensemble members 591-dm 500-hPa height contours (green), member 10 (blue), member 18 (red) and GFS (black)
- Member 10 had right-most track of all ensemble members, while member 18 was farthest left. Their initial conditions were similar.

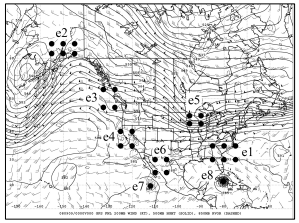
Forecast track from 20 GEFS ensemble members from 00Z 9 Sep 2008 cycle (orange) and Ike best track (white)

- GEFS ensemble mean forecast error smaller than TVCN multi-model consensus

- Initial perturbations in GEFS ensemble showed large spread in the western extent of the mid-level ridge north of Ike
- Disparity in strength and orientation of ridge grew with time
- GEFS ensemble showed large spread in track, with several members near or to the right of the observed best track

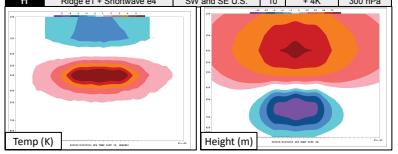
3. Sensitivity Experiments: Design

- Test sensitivity of Ike's track in the NCEP GFS model to the several synoptic-scale features identified by modifying the initial analysis using the NCEP GSI system
- Synthetic observations of temperature are assimilated



Dots represent the approximate locations of observations for GFS perturbation experiments

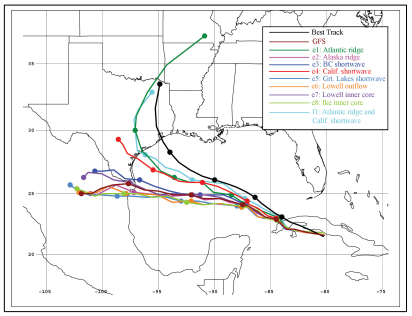
Name	Synoptic feature	Location	#	Strength	Level
e1	Mid-level ridge 'A'	Due north of Ike	6	+4K	300 hPa
e2	Upstream ridge	Southern Alaska	6	-4K	300 hPa
e3	Shortwave trough 'D'	British Columbia	4	+4K	300 hPa
e4	Shortwave trough 'E'	California	4	+4K	300 hPa
e5	Shortwave trough 'B'	W of Great Lakes	4	+4K	300 hPa
e6	Outflow ridge from TS Lowell	Northern Mexico	4	+4K	500 hPa
e7	Tropical Storm Lowell 'G'	Off Baja California	1	+5K	500 hPa
e8	Hurricane Ike	Cuba	1	+5K	500 hPa
f1	Ridge e1 + Shortwave e4	SW and SE U.S.	10	+ 4K	300 hPa



Sample perturbation for experiment e1 along a cross section from 30°N 100°W to 30°N 60°W

- New perturbed analysis produces a balanced increment local to the observation
- Integrate perturbed analysis forward using operational GFS model
- Assimilation / initial time: 00 UTC 9 Sep 2008

4. Sensitivity Experiments: Results



Combining Perturbations

- Experiment **f1** combined weakening of ridge A and strengthening of CA shortwave E
- Greater shift in track when two perturbations are combined
- Change in track primarily due to large-scale downstream influence from shortwave E, which produces a weaker ridge north of Ike than e1
- Timing of onset of recurvature is more accurate than that produced by either **e1** (too fast), or **e4** (too slow)

Summary

- Most perturbation experiments produced little change to Ike's track, as the hurricane moved too far south into northern Mexico or extreme southern Texas
- Track forecasts in the first 24 h are almost identically due west in all cases, regardless of the later evolution
- Largest sensitivity to experiment **e1**, weakening the ridge A north of Ike
  - Allowed Ike to gain enough latitude to eventually recurve
  - Landfall at 96 h more than halfway toward the actual location compared with the operational GFS
- Experiment **e4**, deepening the California shortwave E, also resulted in a northward shift of the track
  - Landfall location approximately halfway between operational GFS and best track

5. Concluding Remarks

- Ike's track was sensitive to the amplitude and orientation of a mid-level ridge to its north, and an upstream shortwave trough over California
- Forecasts of tropical cyclone track remain susceptible to initial condition errors
- Initial condition errors may potentially be reduced via augmentation of the routine observational network and advances in modeling and data assimilation