Hurricane Modeling, Tracking and Damage Prediction… Fighting the Currents/Eddies of Conventional Wisdom!

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Hurricane *Raison d'etre*…

- Competes with earthquakes for federal a$$istance
- Helpful for extinguishing wild fires (sort of)
- News: Hurricane Season at its Peak Now (sort of)
- Costs to Taxpayers
  - Tropical Storm implies (National) Flood Insurance $
  - Emergency Declarations imply quick $
  - $50-100B Florida event implies Federal Bailout (then again, … maybe not)

Modeling Hurricanes *Raison d'etre*… (phmsociety)

- Lessons Learned in Modeling Hurricanes and their Impacts Translate to Other Disciplines/Application Areas
- Real-time, seasonal, long-term time frames
  - Complexity of Forecast Track/Intensity Models (simple+fast *v.* complex+slow)
- Alternative modeling approaches (anti-lemming)
- Retrospective v. Prospective models
- Impacts versus Methodology

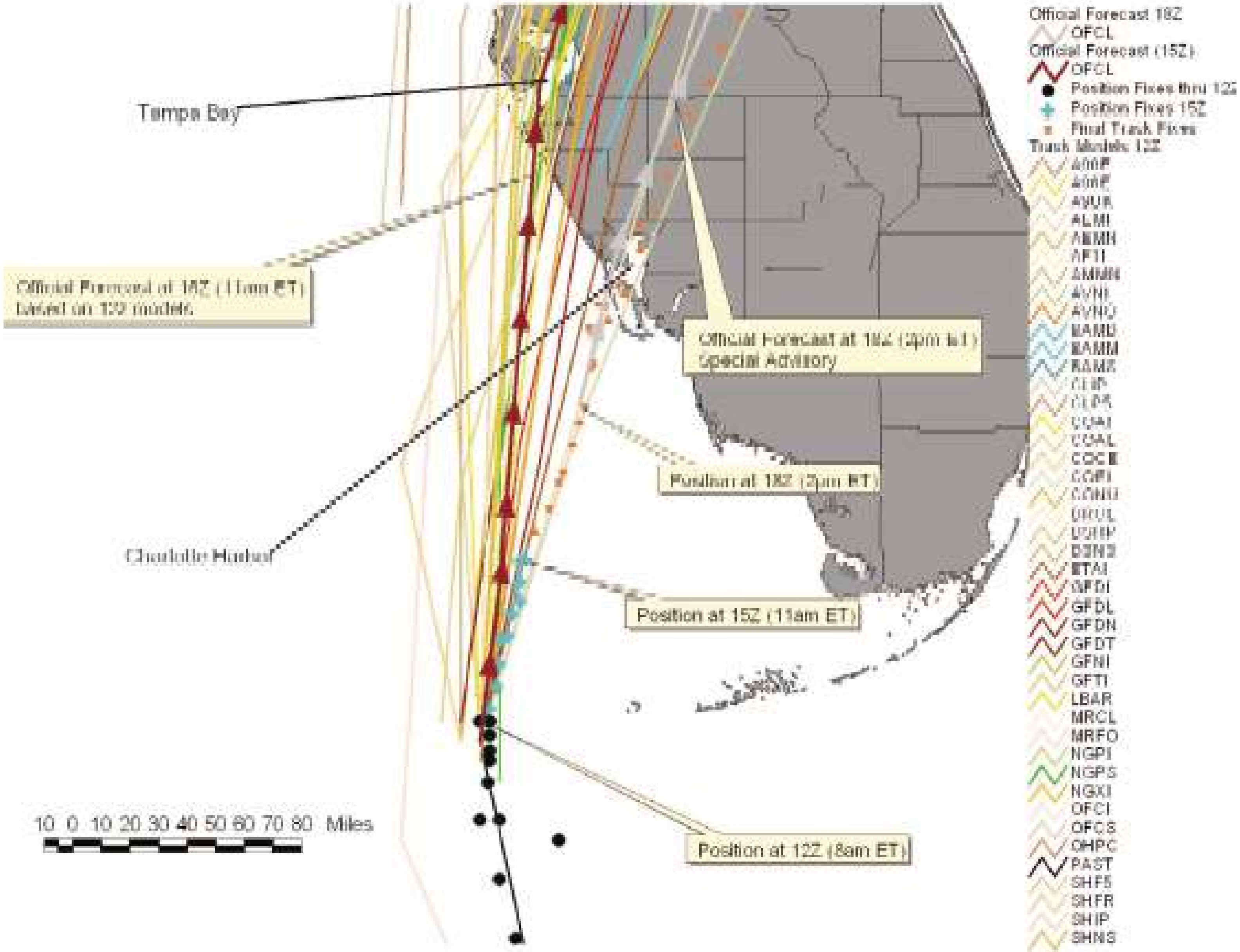


Figure 2. Forecast situation for Hurricane Charley, midday, Friday 13, August 2004.

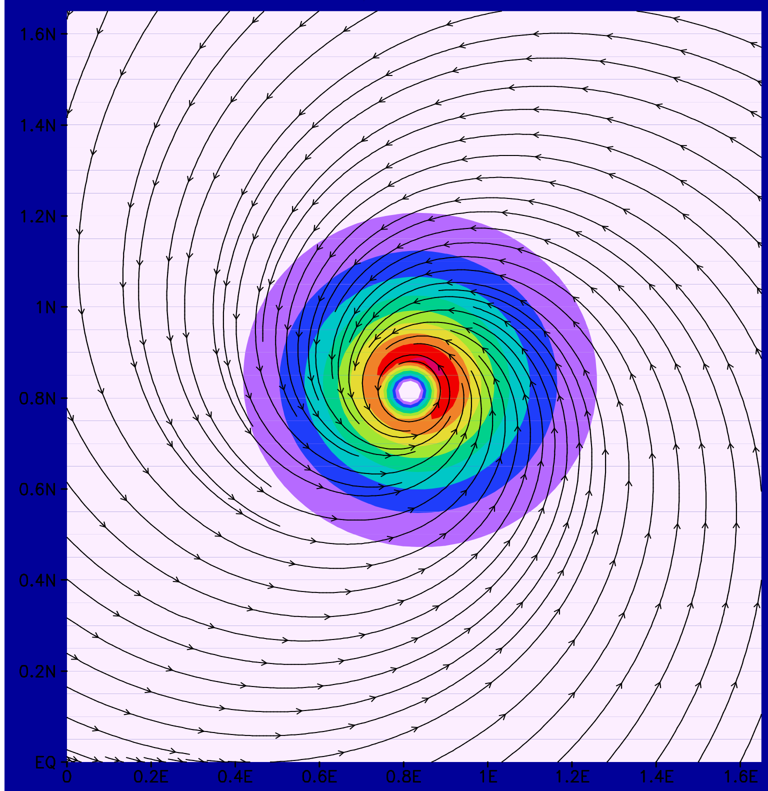
NHC forecast for Tampa Landfall

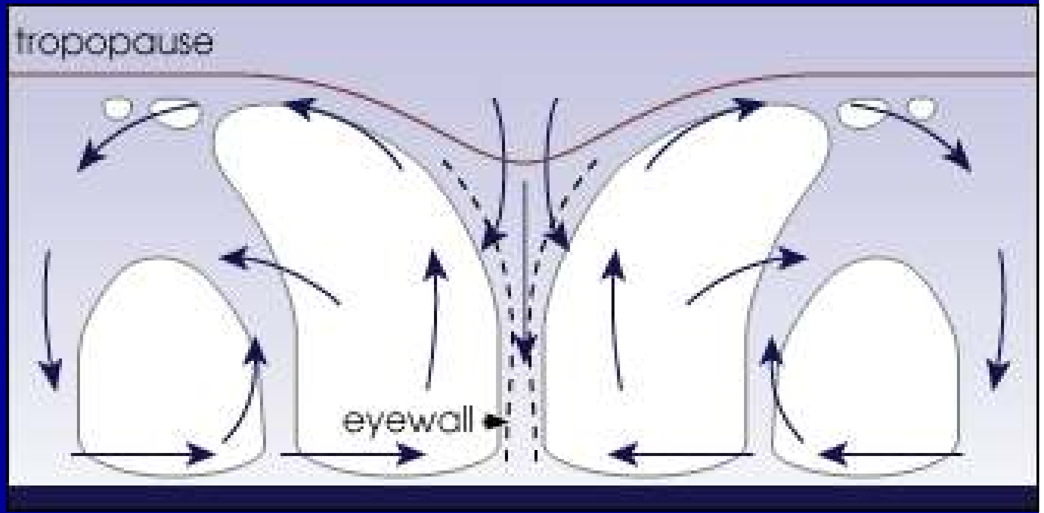
- Charley forward speed of ≈30mph
- 6 hour forecast schedule (11am, 5pm, …)
- Complicated, slow-ish model
- Simpler forecast model with more current initialization would have detected easterly trend
- Avoids "Charley made a sharp right turn"
- Was it a rolling stop? Did it pass "GO" also?
- Cone of uncertainty protects NHC

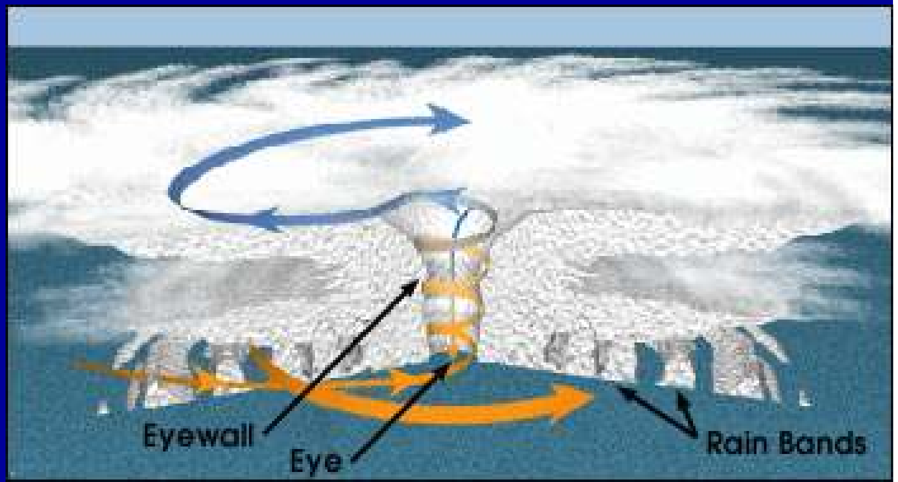
Some paraphrases:

- “Give me 4 free parameters and I can model an elephant; give me one more and I can make it wiggle its trunk.”
- “Models should be as simple as possible, but not simpler.”

Structure of a mature storm

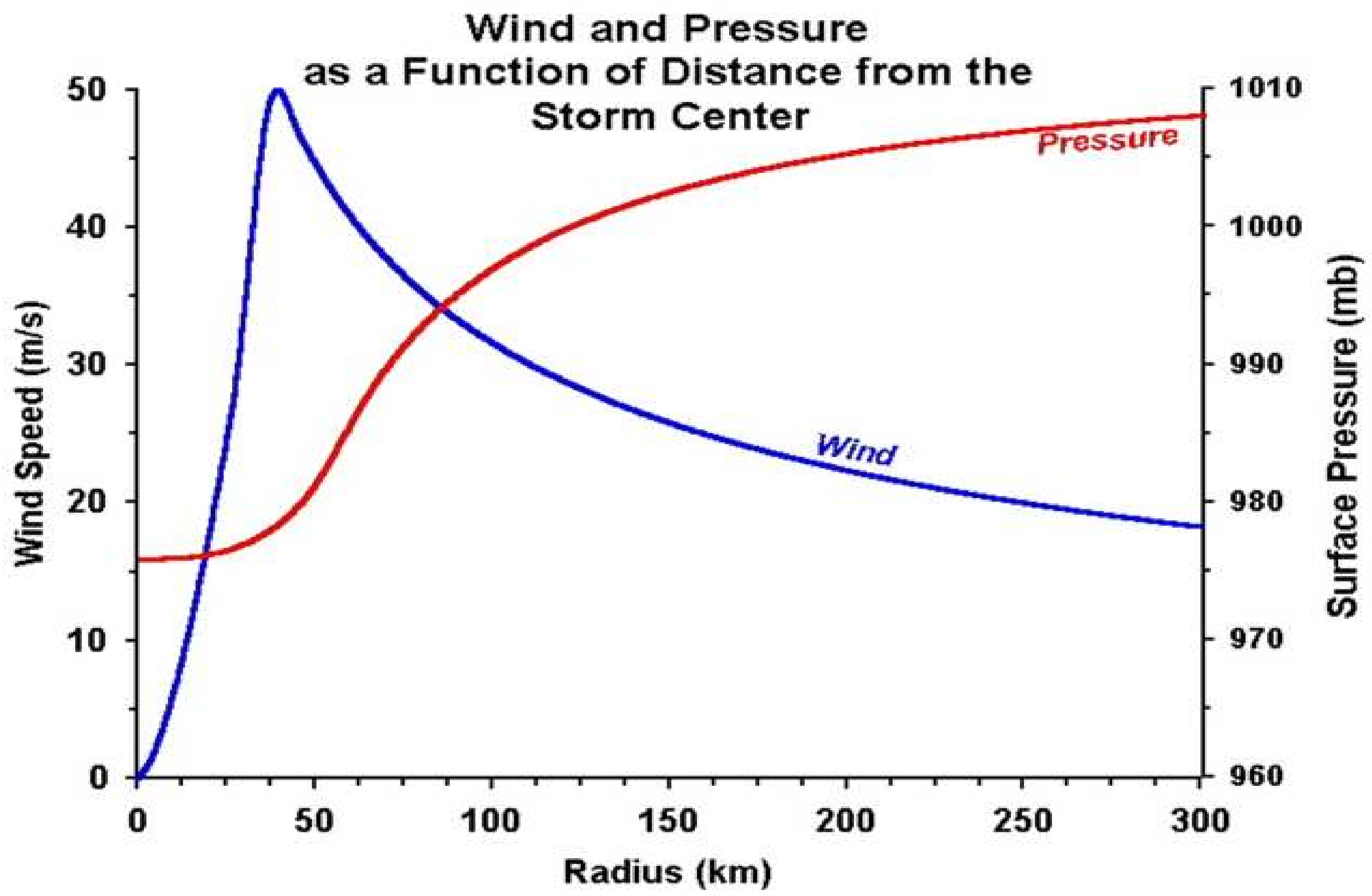




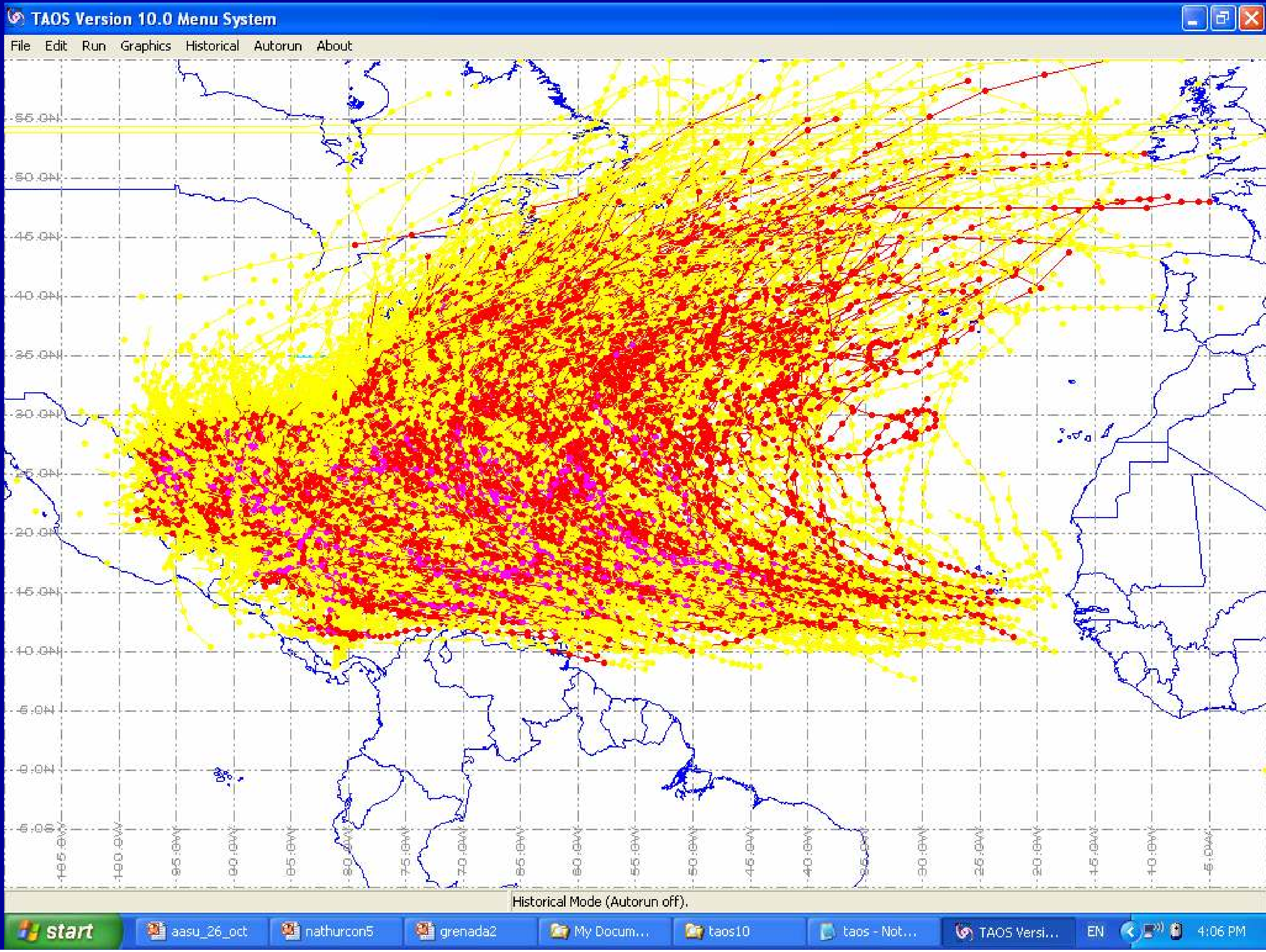


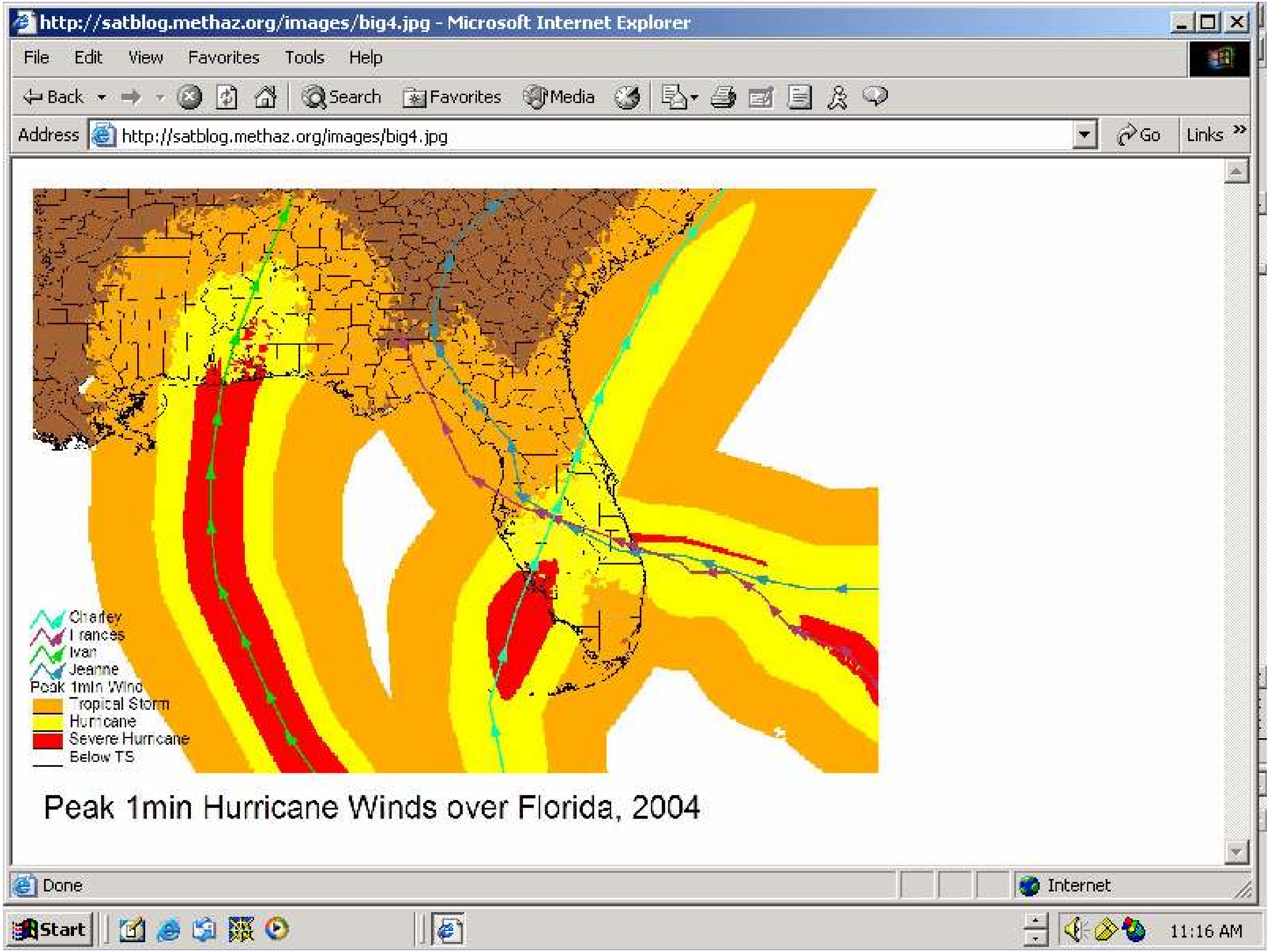
Hurricanes are basically heat engines: warm moist air flows in at the surface, rises and cools in the eye wall, and exits at the top. The potential energy of the warm moist air is converted in to kinetic energy in the form of wind (like a steam engine).

Suggestive of a Simple Model



Atlantic Basin History

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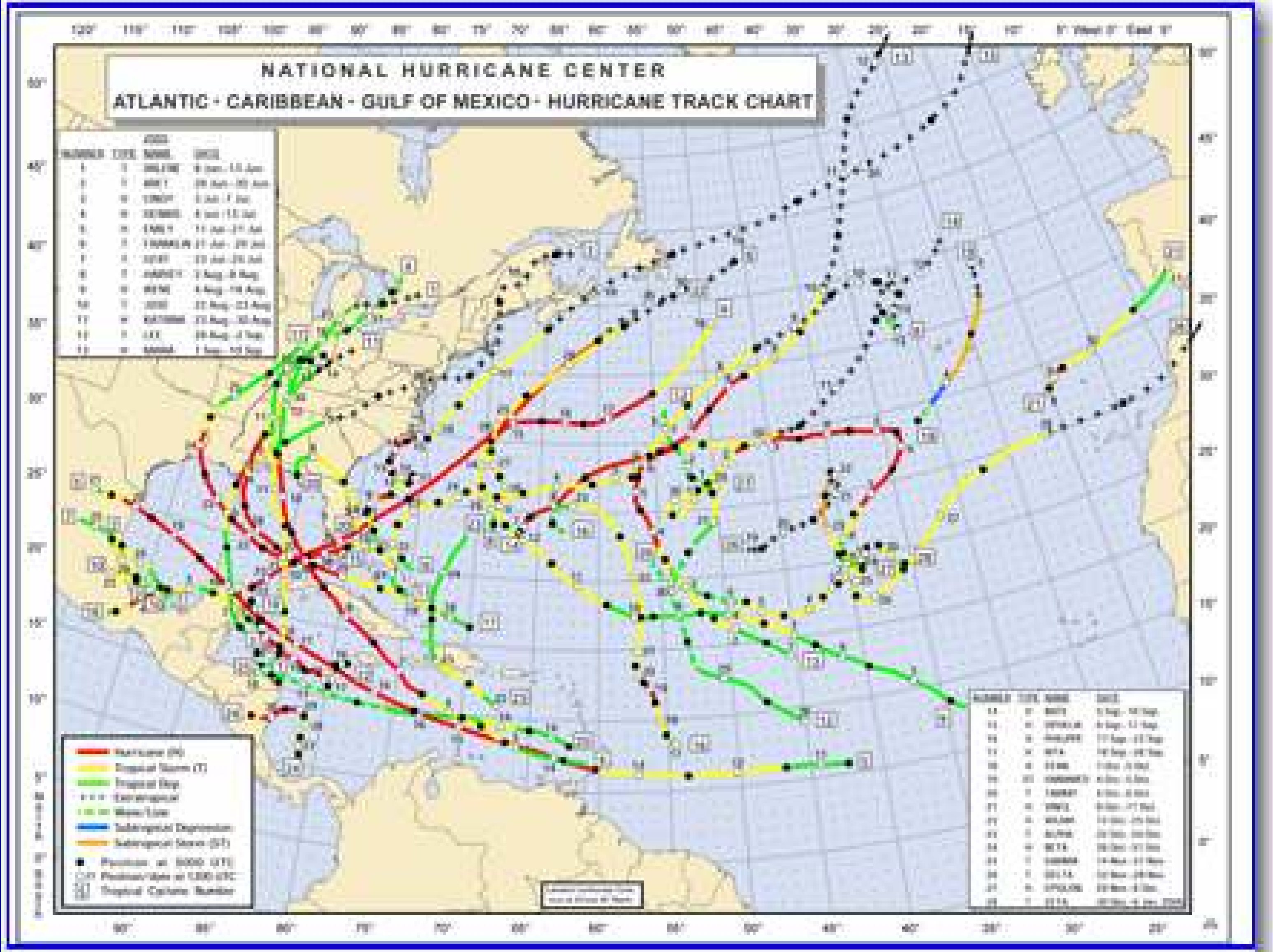


2005 Atlantic Hurricane Season Track Map (click for 310K GIF)*
View or download the 749K PDF

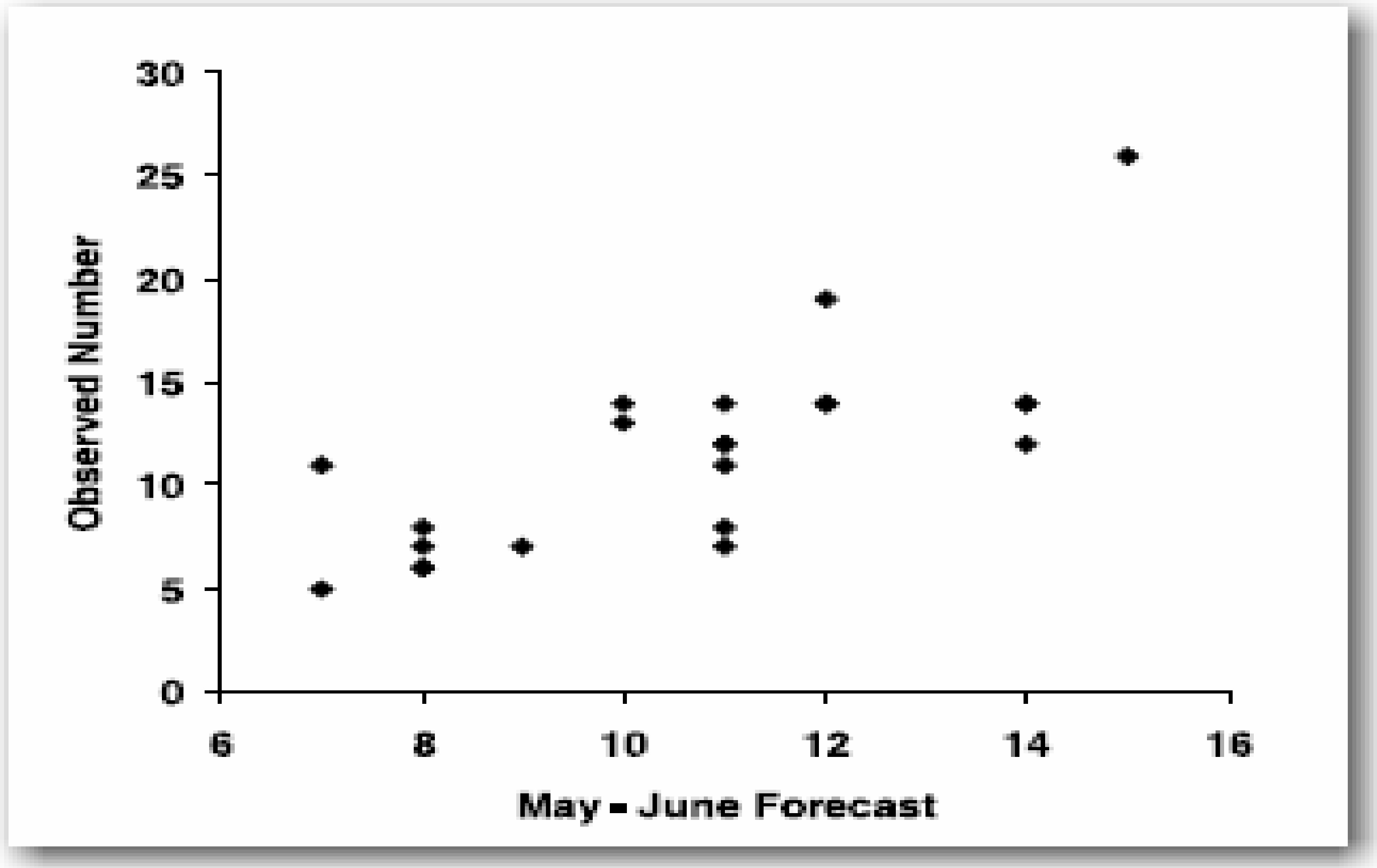
2005 Hurricane Season …

- A-Z, … Delta
- Dennis, **Katrina**, Rita, Wilma among the cast
- Katrina oil disruption dead on (<10,10-30,>30 days)
- Wilma power outage dead on

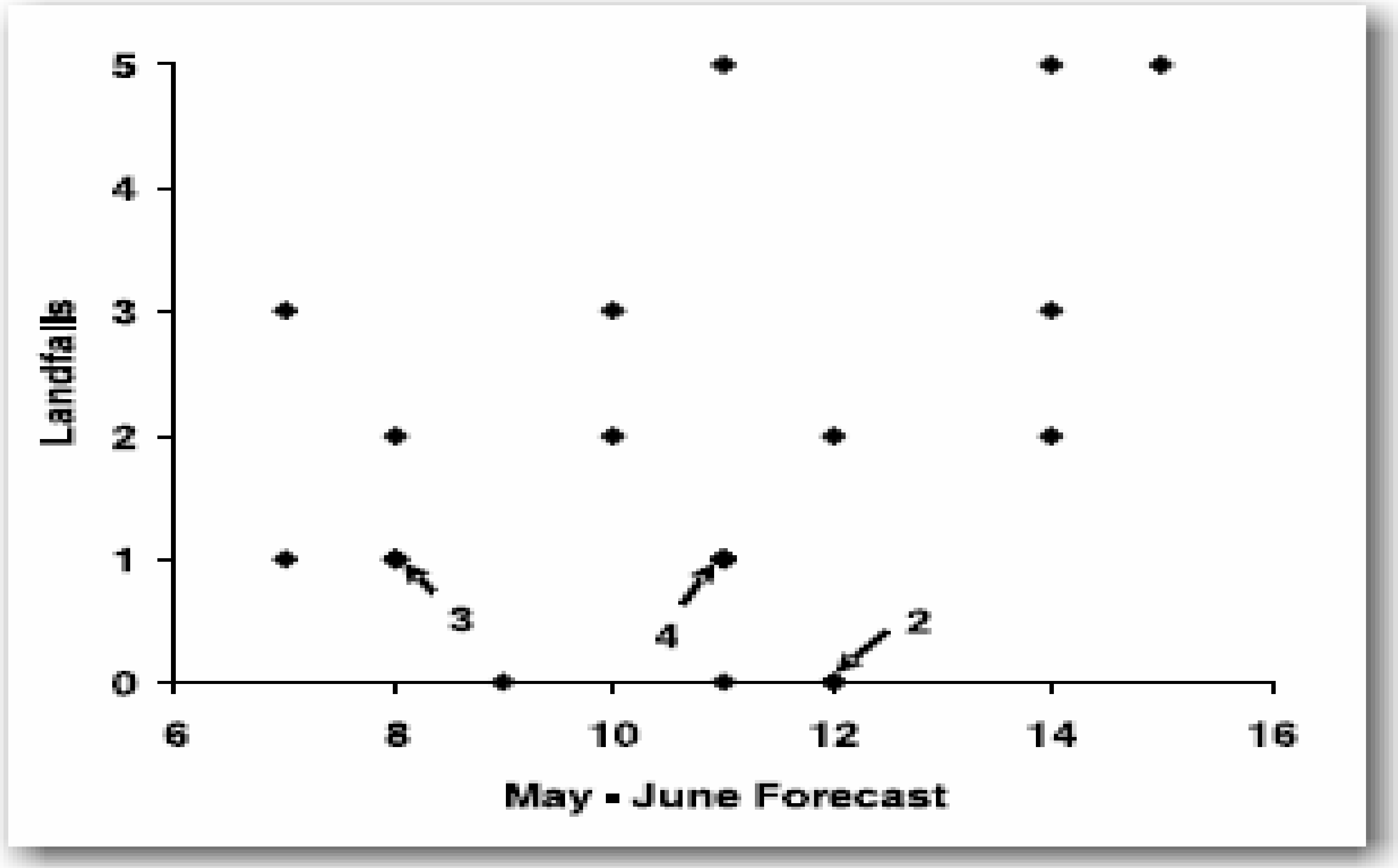
Apocalypse Crowd Energized

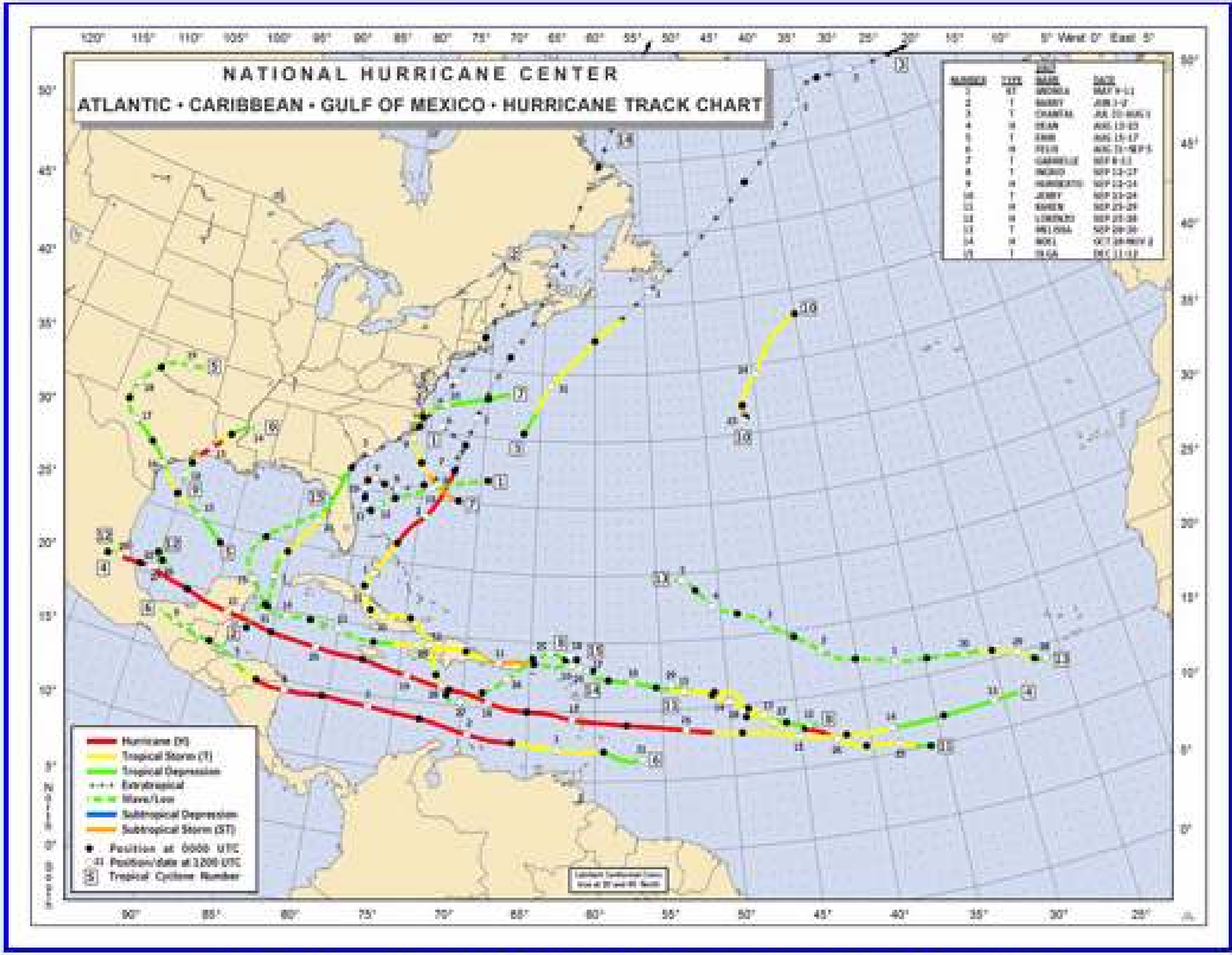
- Assess historical data to support re-insurance implications
- Oops…2006-2008 big duds for Florida
- 2009 looking minimal so far (season not over)
- Then again, who's counting storms?

CSU Bill Gray's Forecasts on # Storms



Number of Landfalls (Total – Fishstorms)
(What if you "knew" the # of storms?)



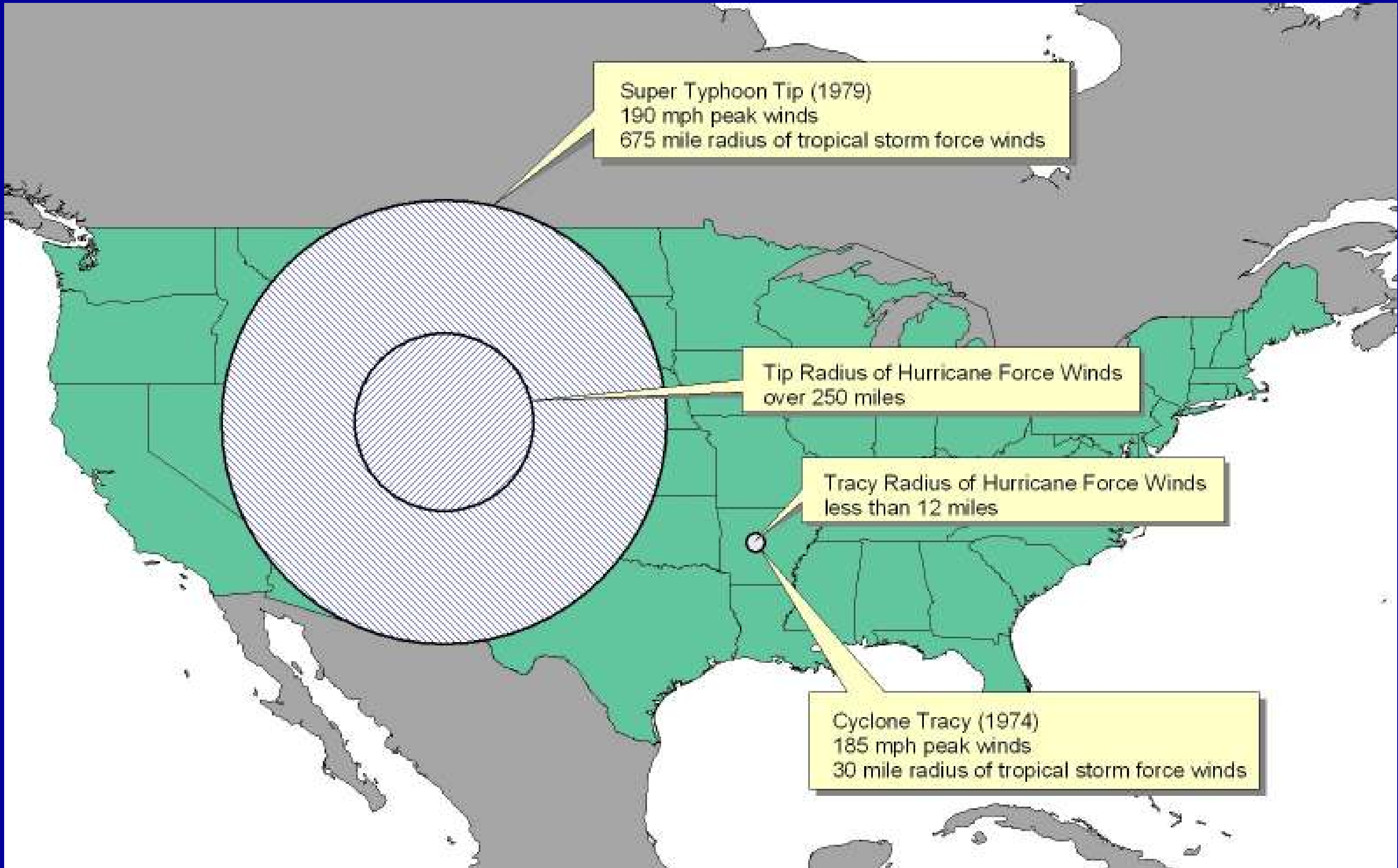


2007 Atlantic Hurricane Season Track Map (Click for 500K JPG)

2007 Season—Not Really a Dud

- Hurricane Dean romped through Gulf of Campeche
- Major Mexican Oil Production Area disrupted—media coverage focused on Brownsville, TX
- Led to additional contracts for forecasting oil/gas disruption

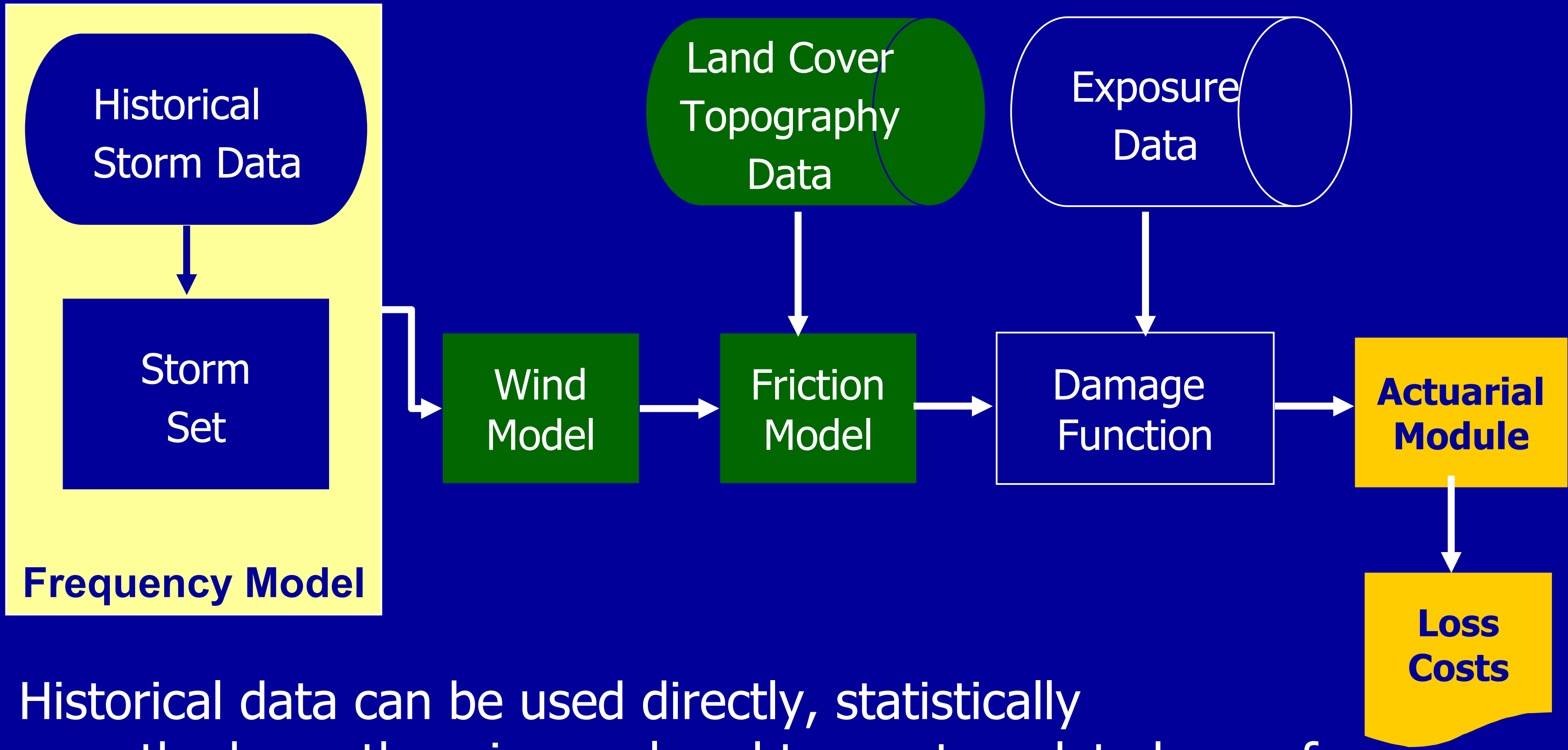
The American Statistician, May 2006
A ‘cane is a ‘cane is a ‘cane?



Computer Models for Loss Estimation to Set Insurance Rates (long term problem)

- FCHLPM est. 1996 (insurance fiasco 1992, following Hurricane Andrew)
- 4 Proprietary (Private) Models
- 1 Public Model (Flor. Int. Univ.) more recent
- Professional Audit Team to Review the Models against Standards
- Models submitted follow same basic structure
- Modelers required to run LHS SA/UA exercise

Traditional Loss Models



Historical data can be used directly, statistically smoothed, or otherwise analyzed to create a data base of storm characteristics used to create the storm set for simulations (what we do).

Alternative modeling approaches

- Instead of Traditional Monte Carlo approach
  - Run entire historical storm set
  - Take annual maxima and fit distributions (Weibull) for "smoothing" (retrospective)
  - Run global climate model forward 100+ years to generate "synthetic" hurricane tracks and intensities (prospective)
- No axe to grind on Model components (e.g., the Watson wind field or the Johnson damage function)

KAC broad approach different

- Nine wind fields
- Four surface friction methods
- Nine damage (vulnerability) functions
- Three frequency methods (2 retrospective, 1 prospective)
- 9 x 4 x 9 x 3 =   972 models

Other options include changing historical storm data bases, exposures, and other storm assumptions. Result is thousands of possible outcomes.

Frequency of Occurrence

- Pure historical data approach (1320 storms from 1851-2004) retrospective
- Fitted wind distribution using Weibull distribution for annual maxima at each site (Johnson and Watson, 1999). "Smoothing" of historical results. retro.
- Climate Model using 130 year run of a fully coupled ocean-atmosphere model, NCAR's CCSM coupled with a mesoscale (high resolution) nested model, the PSU/NCAR MM5 model, to produce a higher resolution (4km) analysis (Watson and Johnson, 2007) prospective

Massive computing requirements.
Three distinct approaches.

Input Data Bases—Issues Everywhere

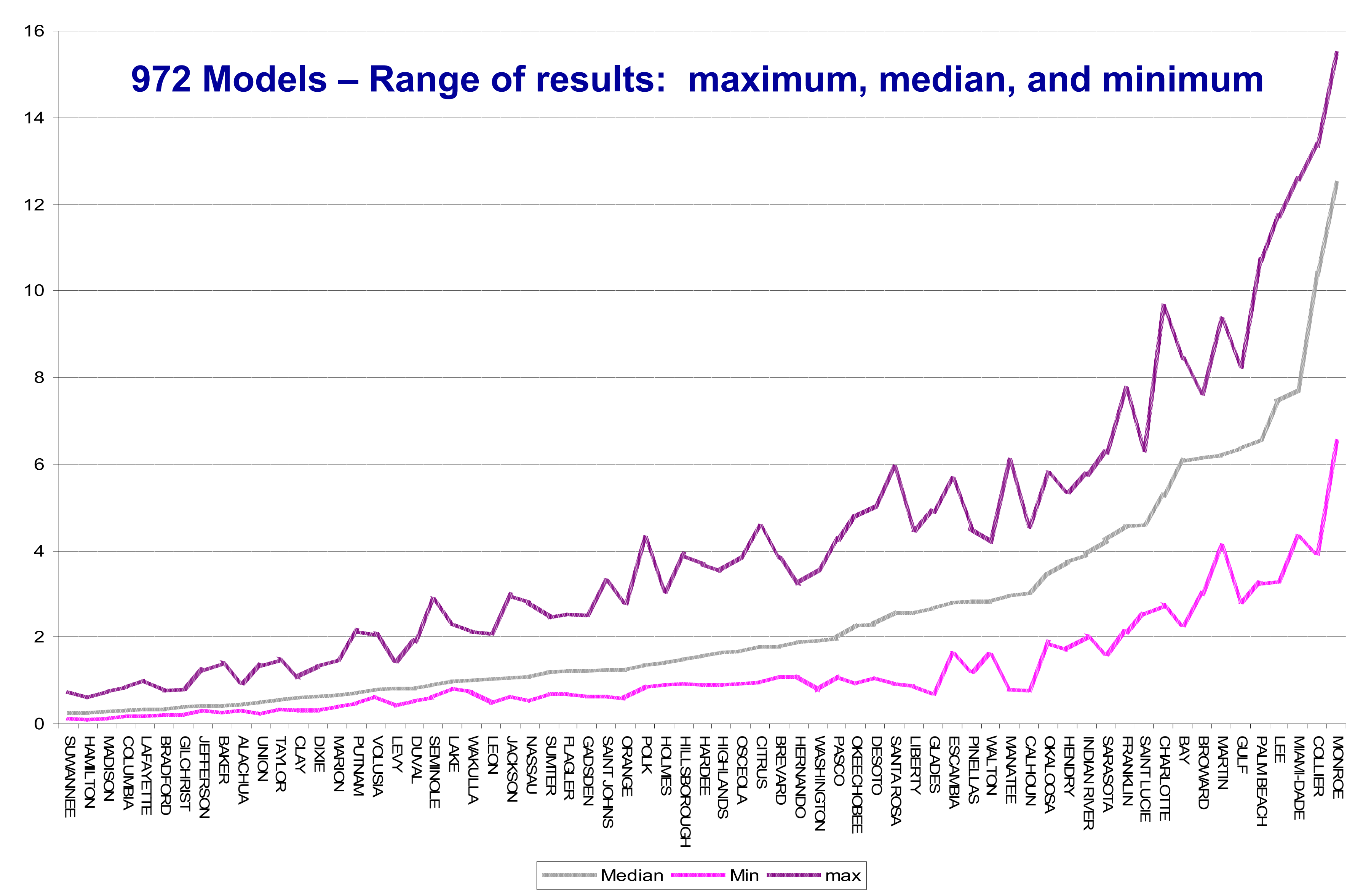
•Digital Elevation Model (topography)
Not all models use topography
Ridge and valley effects important in upland areas

•Land Cover/Land Use
Friction effects to adjust wind impacts on structures at surface
Annual Satellite updates

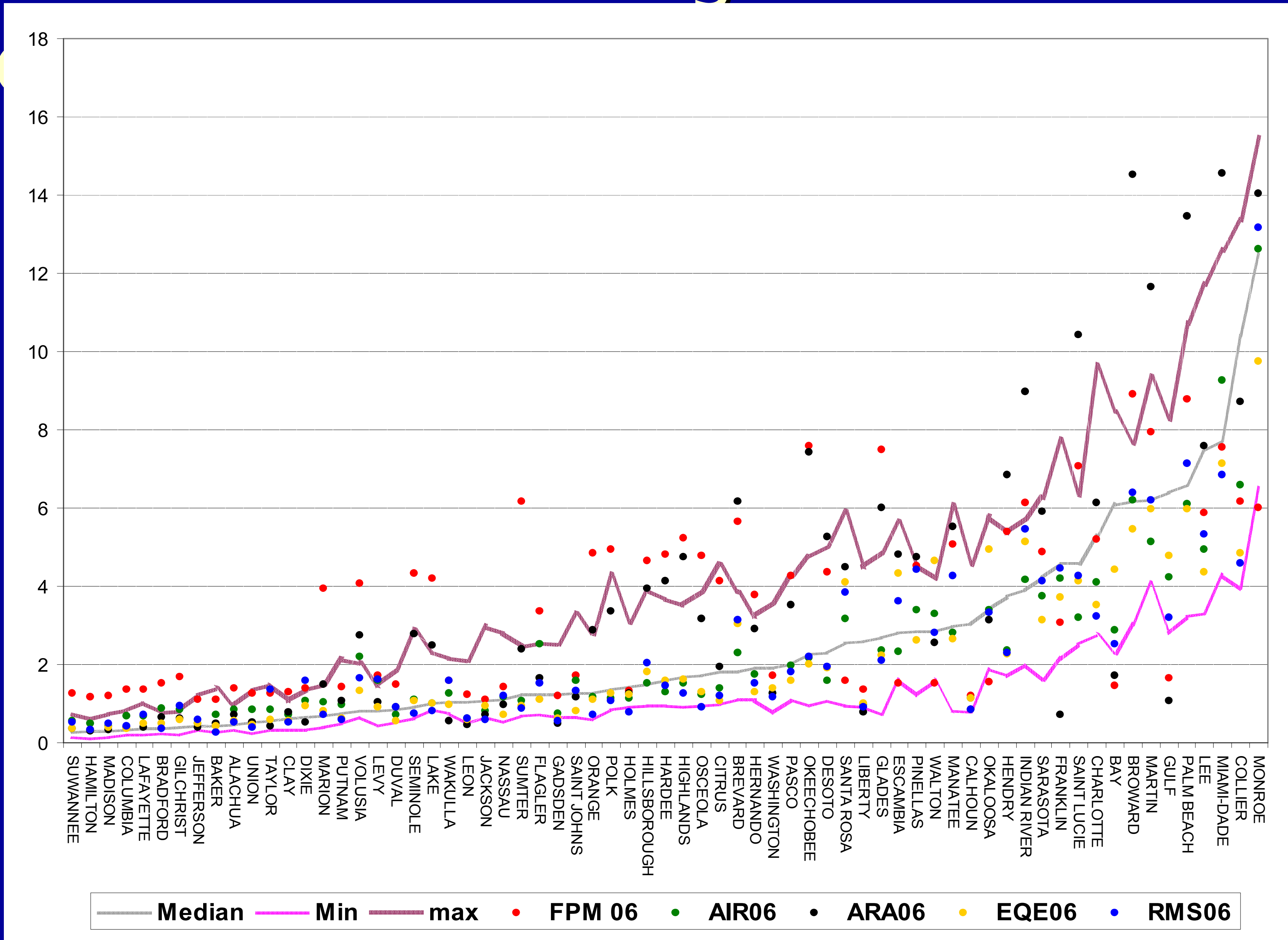
•Historical Storm Track and intensity data
Required to simulate individual storms for comparison with observed losses. Used as a basis for the determination of frequency of occurrence and other storm characteristics

•Exposure data set
Location, characteristics, and value of properties at risk

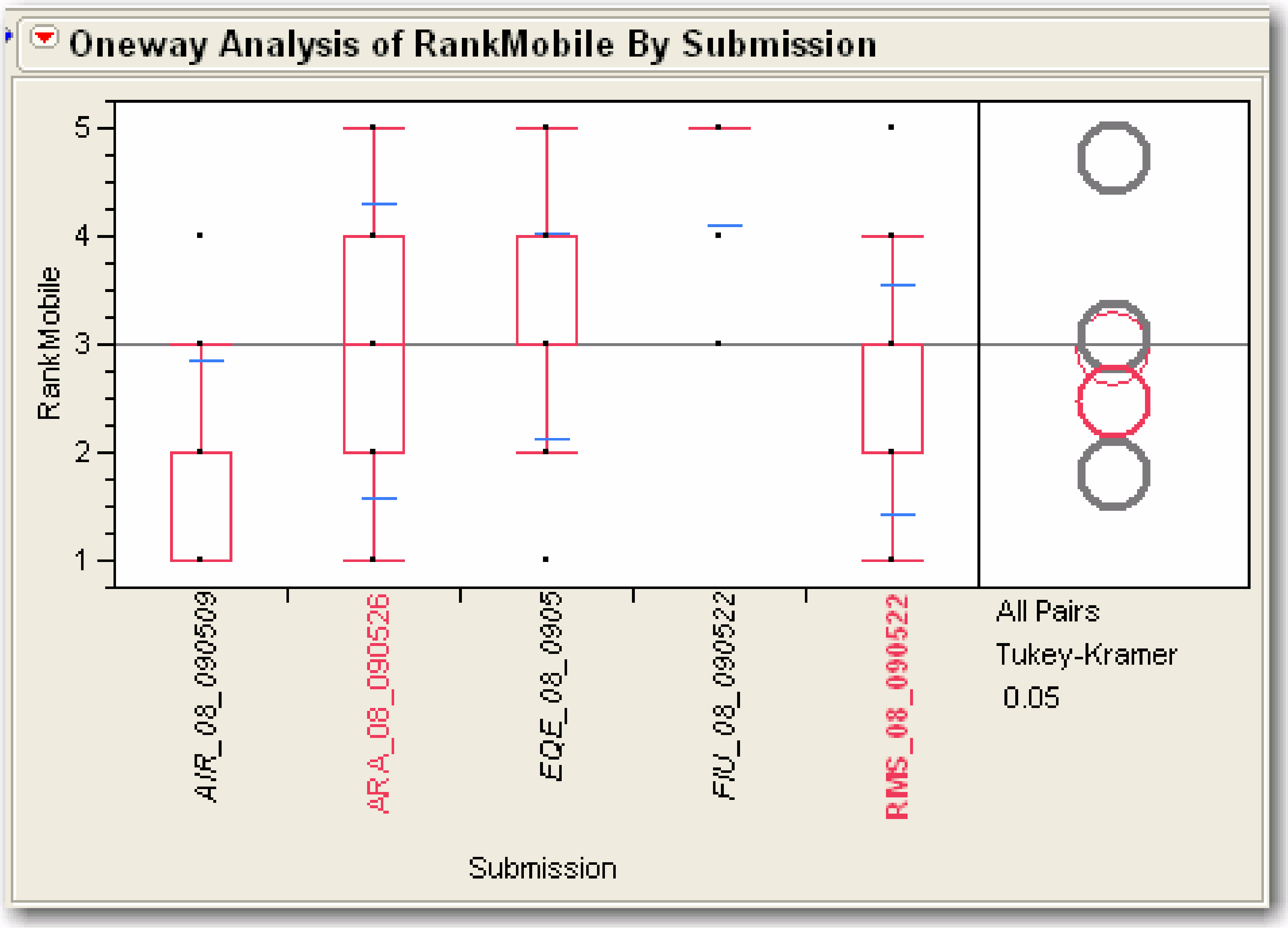
Results from Public Domain Models vs. Ours



All 5 Models v. Range and Median



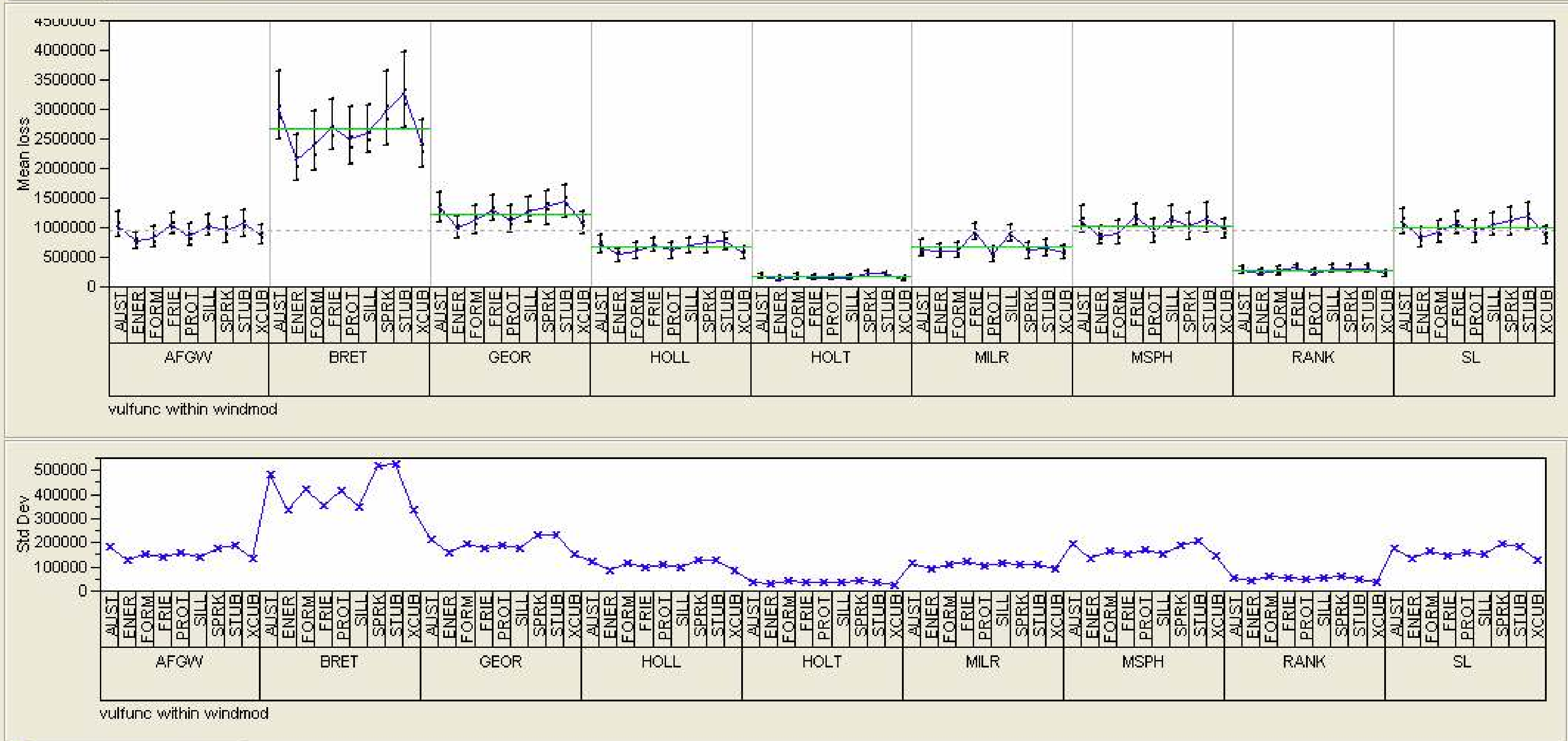
Comparing Models for Manufactured Homes



Variability Chart for Miami-Dade

Variability Gage

Variability Chart for Mean loss



Analysis of Variance

Variance Components

Component	Var Component	% of Total	20 40 60 80	Sqrt(Var Comp)
windmod	5.30866e11	91.1		728606
vulfunc	1.15803e10	2.0		107612
windmod*vulfunc	4406420381	0.7561		66381
Within	3.59142e10	6.2		189511
Total	5.82767e11	100.0		763392

Requirements for multi-model approach

- Hardware – availability of Beowulf class supercomputer
- Software – optimization of code and data sets
- Availability of data bases
- Meshing of hardware and software techniques
- Openness to algorithms outside classical meteorological community

Summary: Why Models Vary and Why Forecasts Vary

- Model component selections, especially wind field.
- Meteorological input variables very sensitive to assumptions, more sensitive than our ability to measure. Can drive wind model selections.
- Land Cover and other support data bases out of date can make significant difference.
- Spatial Aggregation and representation level of aggregation can bias results; Even GIS projections can be tricky; ZIP Codes, especially in rural areas can introduce significant errors.

Where do we stand?

- While we ***can't*** expect individual models/forecasts to agree, we ***can*** understand the variation we should expect from models.

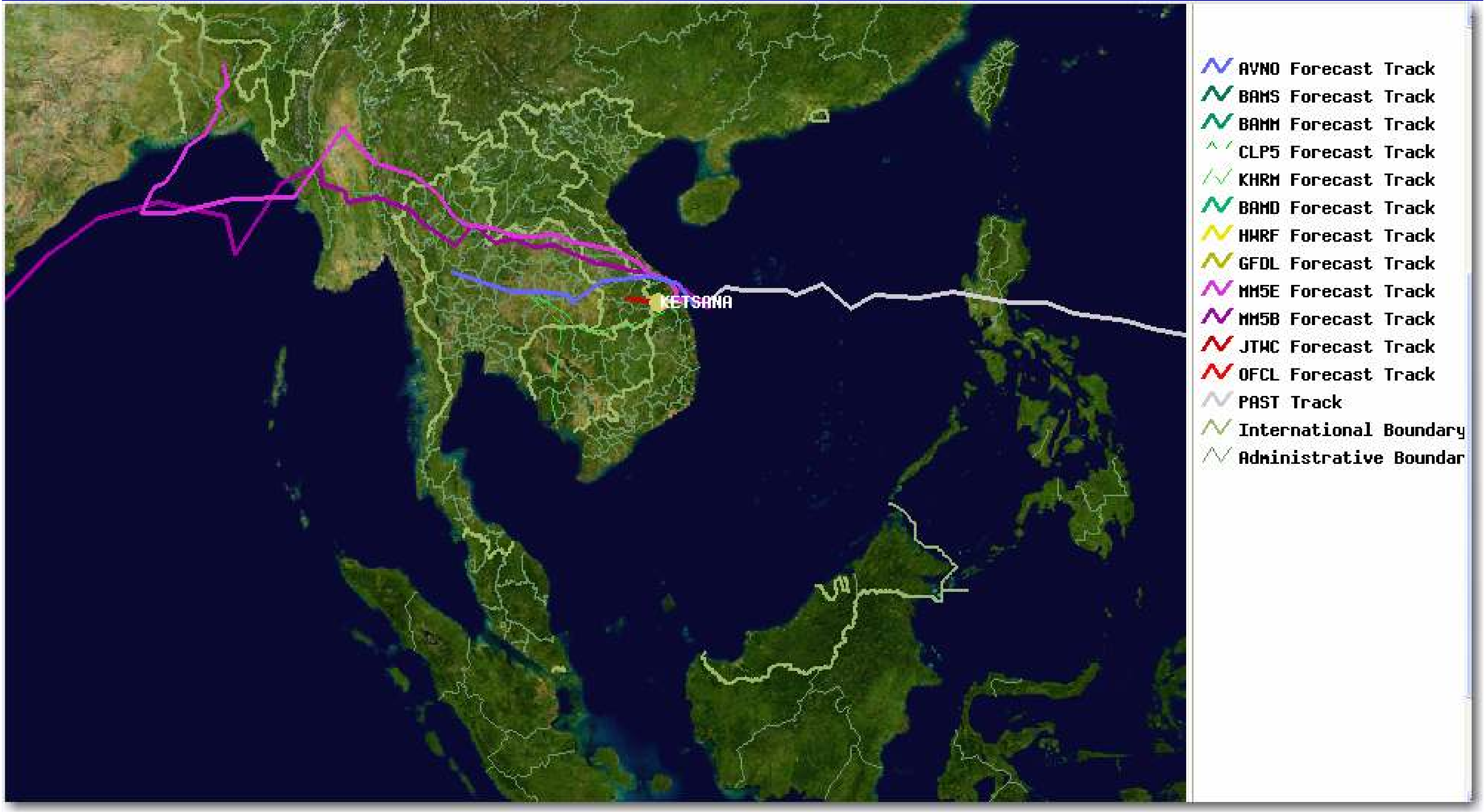
- With the results of the above studies, especially the results of nearly one thousand public domain hurricane loss models, the Commission now has a baseline against which to evaluate individual model submissions.

- Instead of battle of the models, we favor insights gained from multiple models.

Modeling Take-aways for PHM Society

- Lessons Learned in Modeling Hurricanes and their Impacts Translate to Other Disciplines/Application Areas
  - Real time or more leisurely time frame drives potential approaches
  - Alternative modeling approaches more rewarding (riskier—non-traditional)
  - Requires publications in application field (BAMS)
  - Retrospective (historical and Weibull smoothing) versus Prospective Global climate model approach
  - Impacts versus Methodology = Results versus style
  - Pinch from other disciplines (quantum physics pde algorithms or gage R&R multi-vari chart)

Ketsana, 29 September 2009



Thanks to …

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- PHM Society

http://hurricane.methaz.org