Estimating and Forecasting Tropical Cyclone Intensity at the National Hurricane Center

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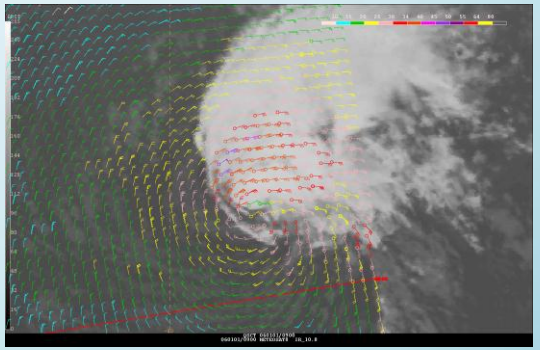
NHC Definition of Intensity

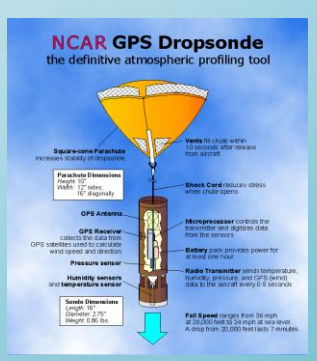
- The maximum wind, averaged over a 1 minute interval at an altitude of 10m, associated with the circulation of the tropical cyclone at a given point in time

Note: With very few exceptions, direct measurements of this quantity are not available.

Sources of Intensity Information

- Satellites
  - Geostationary (Vis/IR)
  - Microwave soundings (AMSU)
  - Scatterometer surface winds
- Surface observation
  - Ships
  - Buoys
  - Land Stations
- Aircraft Recon
  - Flight Level Winds (adjusted to surface)
  - Dropsondes
  - SFMR
- Radar
  - Land-based (WSR-88D)
  - Airborne





Estimating Intensity: Real-Time

- Different instruments/sources may provide very different estimates
- The operational intensity is typically a blend of these, with some consideration given to the continuity of operations

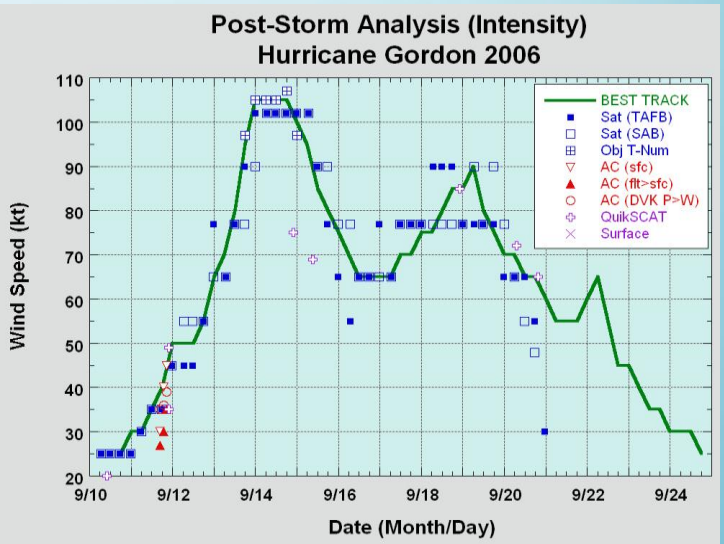
Example: Hurricane Bill 19 August 1800 UTC

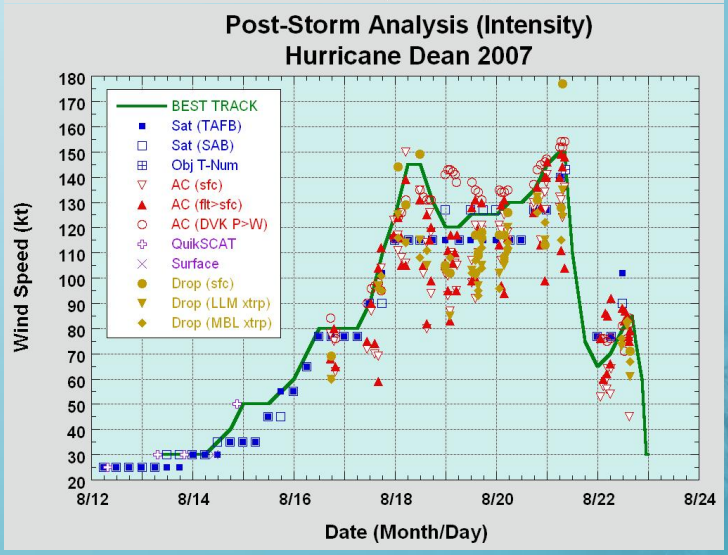
- Dvorak
  - TAFB: 6.5/127 kt
  - SAB: 6.0/115 kt
  - ADT: 6.4/125 kt
- Recon
  - SFMR: 102 kt
  - Flight-Level adjusted: 122 kt
  - Dropsonde WL150: 111 kt
  - Dropsonde MBL: 111 kt

- OFCL at 1800 UTC: 115 kt

Estimating Intensity: Post Storm Analysis

- Specialists will re-evaluate the intensity in the best track during the post-storm analysis.
- Post-storm analysis includes data that may not have been used in real time due to data latency or availability issues





Intensity Uncertainty

- Landsea (2012) quantified uncertainty in the best track by polling the Hurricane Specialist Unit
- Results stratified by the strength of storms and the observations available

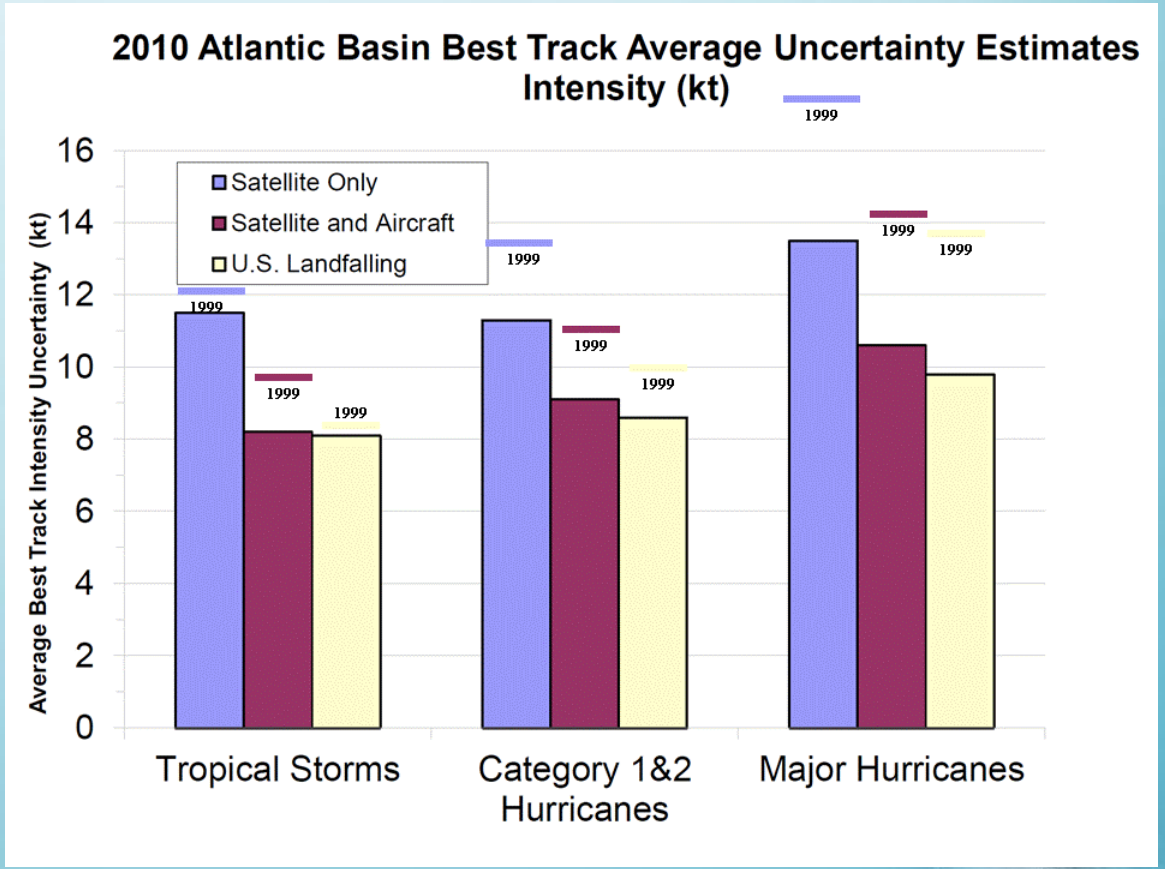


Figure 3 from Landsea (2012)

Intensity Uncertainty

- Torn and Snyder (2012) quantified intensity uncertainty by verifying satellite-based intensity estimates against best-track data during times where reconnaissance data was available

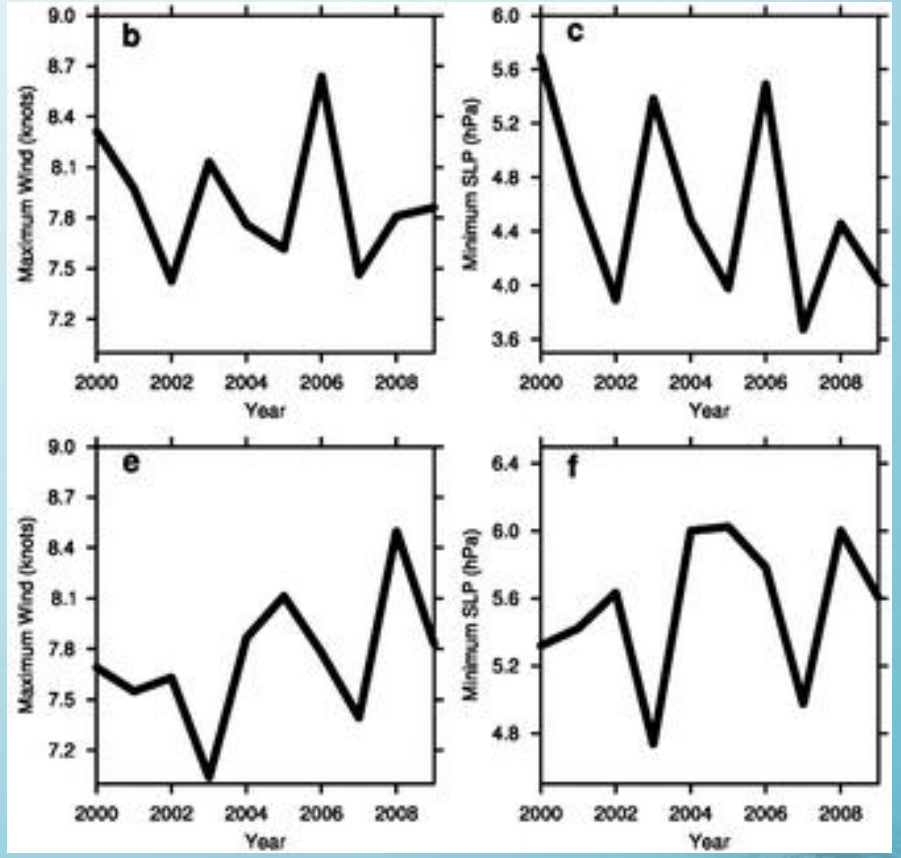
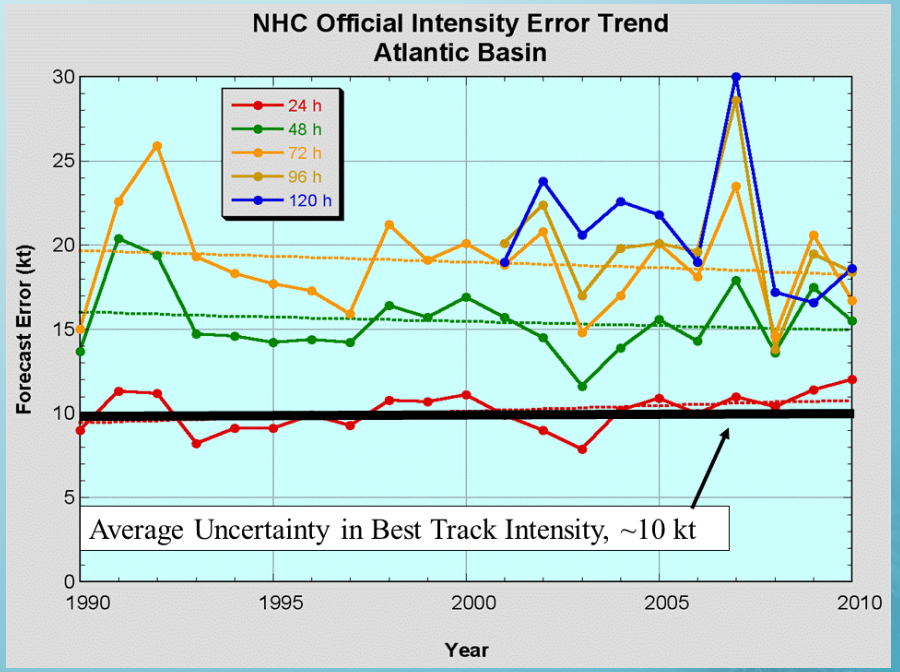


Figure 11 from Torn and Snyder (2012) Top graphs are Atlantic storms, bottom are E. Pacific

Implications of Intensity Uncertainty

- Both studies suggest that it may be difficult to reach the HFIP goal of a 50% reduction in intensity error by 2018 for 1-2 day forecasts.
  - Would require an improvement in our capability to observe intensity
  - 3-5 day errors still much larger than the uncertainty

How does an initial intensity of uncertainty of ~10 kt impact the ability of a model to make a 4-5 day intensity forecast?



Forecasting Intensity

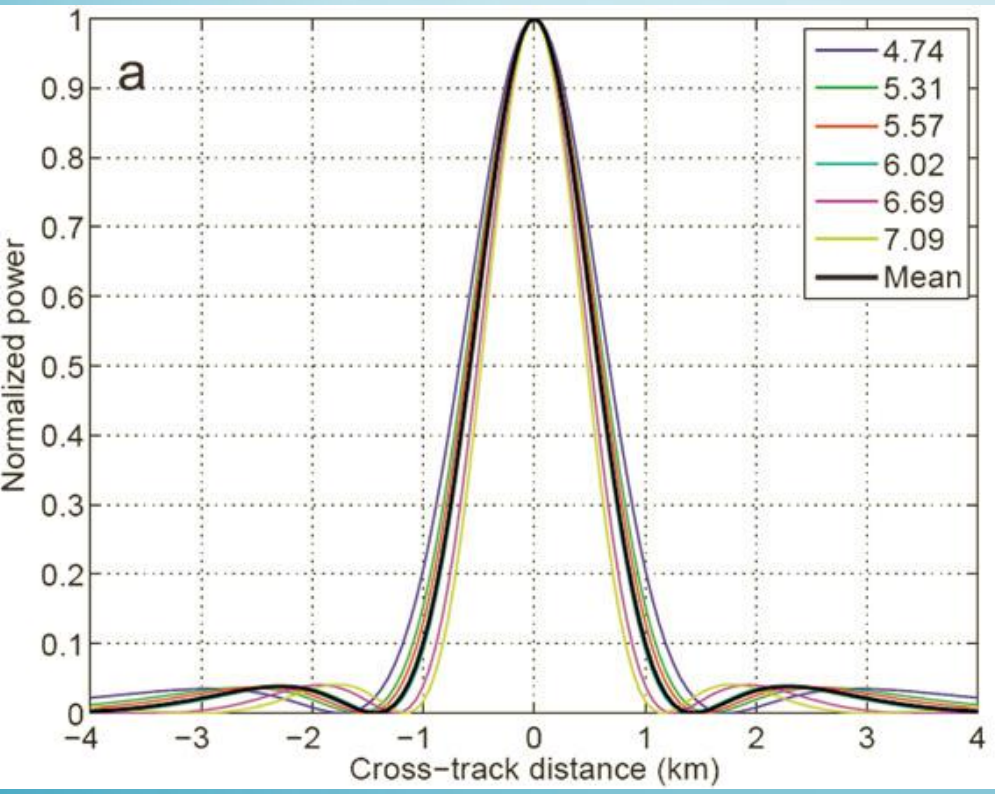
- Dynamical models are interpolated over time to create "early" versions that are used for the forecast.
  - HWFI, GFDI, etc
  - Statistical models run quickly, and are based on the 6-hr old model runs, so interpolation is not necessary
- NHC Forecast typically near the intensity consensus IVCN or TV-15 (includes HFIP models accepted for intensity)
- May depart from the consensus based on:
  - Persistence
  - Obvious signs in the environment (cooler waters, increasing upper-level winds, etc)
  - Climatology
  - Perceived bias of a given model for a particular storm or situation
  - Qualitative assessment of global models

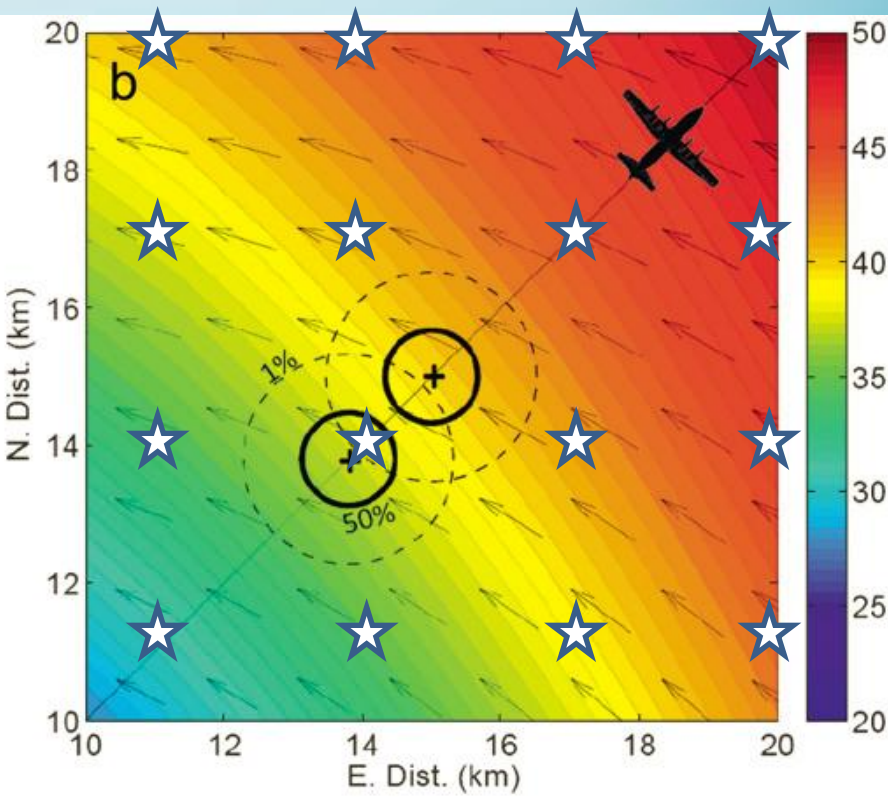
Forecasting Intensity: Interpreting Model Output

- Dynamical models produce explicit intensity forecasts based on the model's representation of a 10m (or lowest model level) wind
- Not clear if this is always appropriate based on model resolution and physics
- Intensity can change a lot over a short period of time, unclear what value is most appropriate
- Different models use different trackers to produce intensity values

Forecasting Intensity: Interpreting Model Output

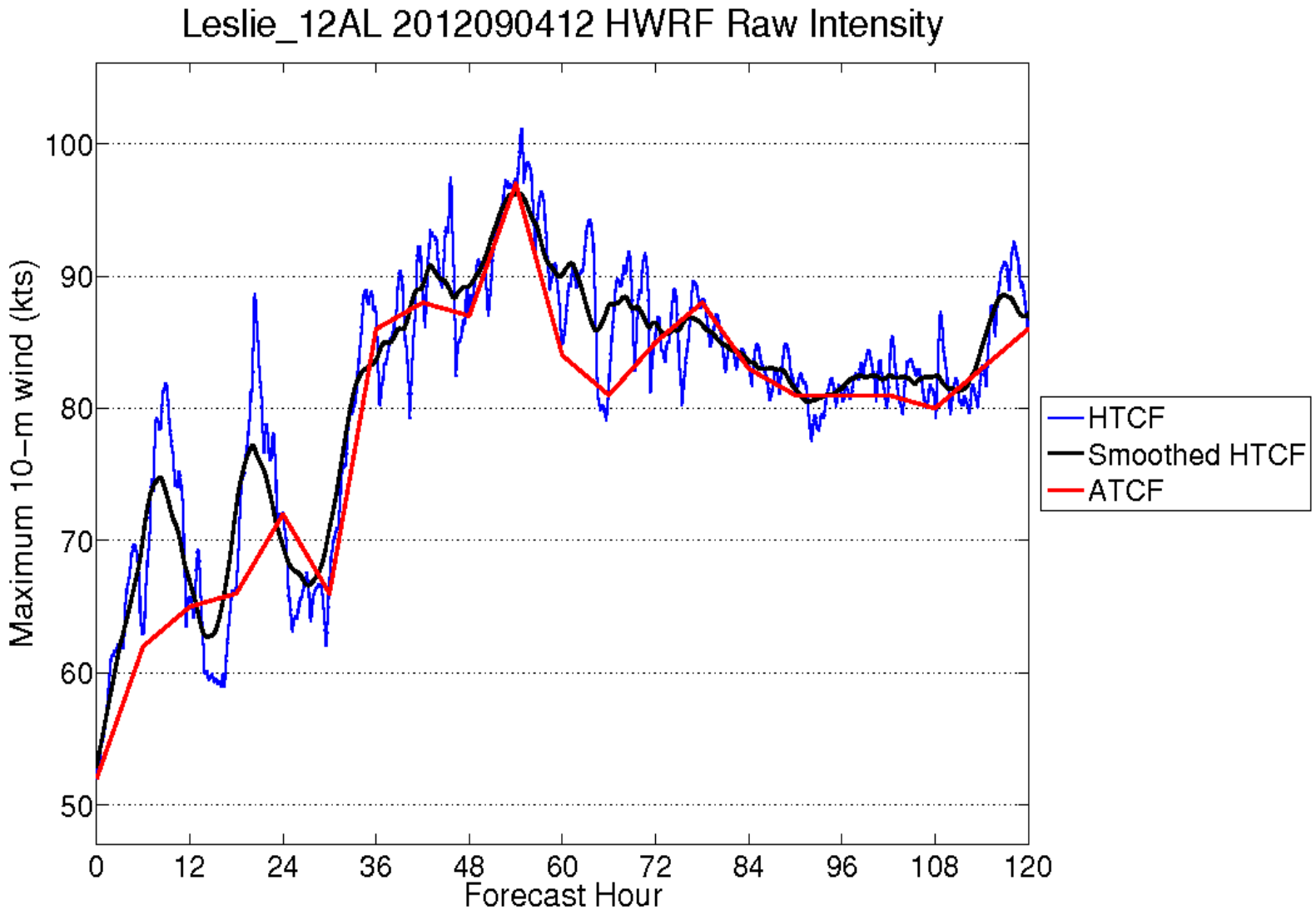
- At 10,000 ft, SFMR has a 50% power footprint with a diameter of 1.3km, (1% power = 2.8km)
- 10-s averages from SFMR are used to determine intensity operationally
  - Resulting footprint is smaller than the gridspacing of most real-time models



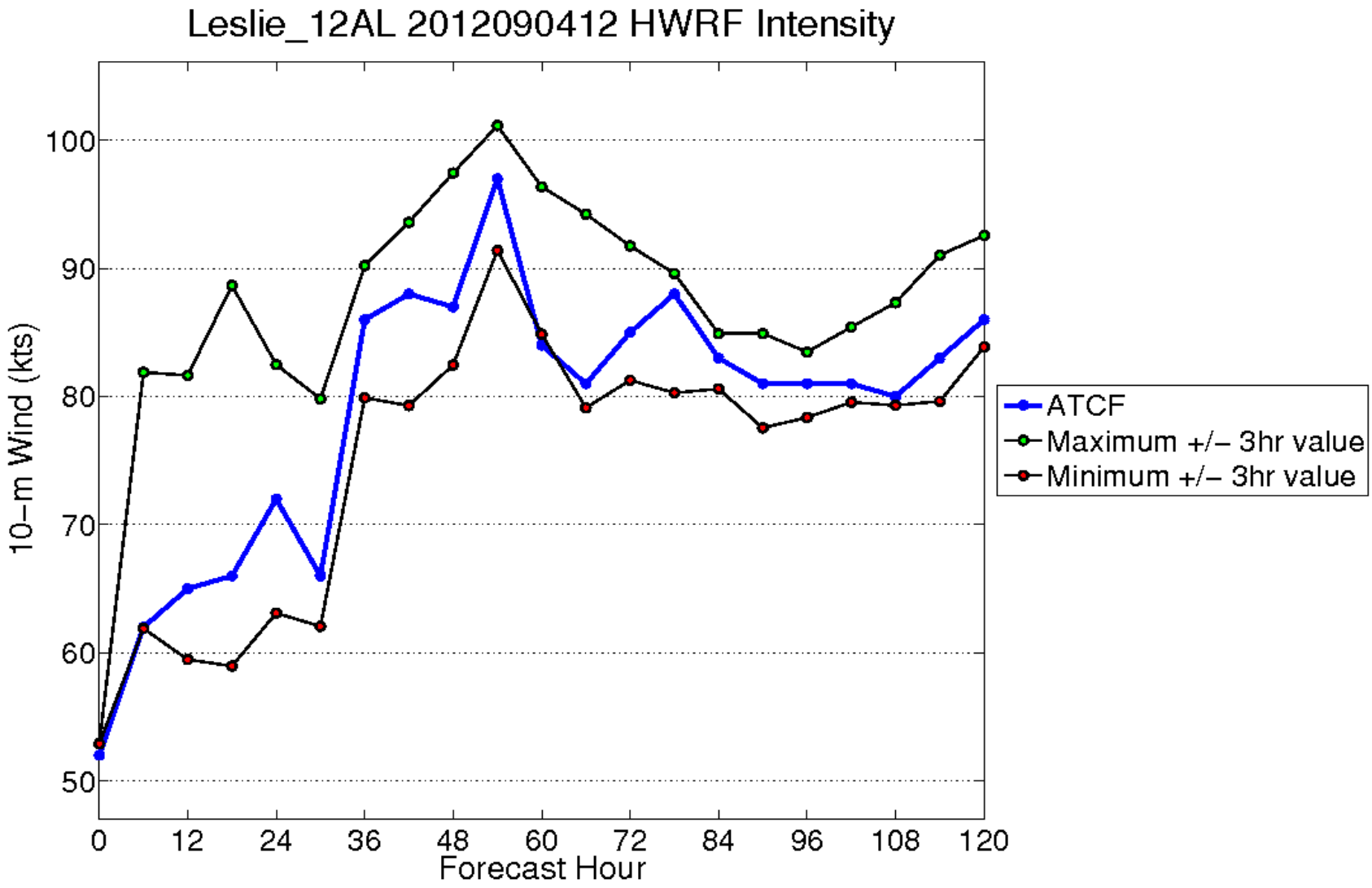


Modified from Figure 7 Uhlhorn and Nolan (2012) Figure 7

Forecasting Intensity: Interpreting Model Output

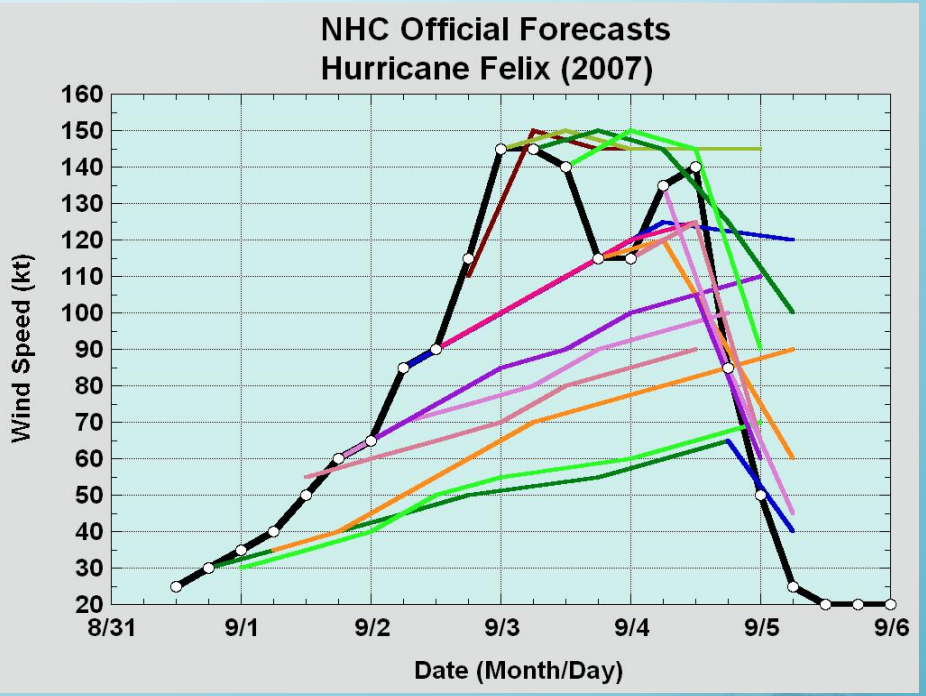


Forecasting Intensity: Interpreting Model Output



Forecasting Intensity: Sources of Forecast "Busts"

- Primary concern: Rapid intensification and weakening
  - NHC forecast tends to be conservative
- Eyewall Replacement Cycles
- Land interaction and landfall timing



NHC Intensity "Wish-List"

- Improved/Additional RI and Eyewall replacement cycle guidance
- Magnitude and location of maximum 1-minute sustained 10m wind speed for each minute through integration; full wind field at hourly intervals; radius of 34, 50, 64 kt winds in each quadrant at hourly intervals
- Probability distribution of intensity change for ensembles, multi-model or single model, including Rapid Intensification
- Forecaster selectable layer analysis of moisture and wind (shear) fields
- Simulated radar/microwave imagery from regional models
- Guidance on the sensitivity of forecasts based on the model initialization
- Ensemble products which show the sensitivity of the intensity forecast to the track forecast

Summary

- The true intensity of a tropical cyclone is almost never known
  - NHC-determined intensity is ultimately based on a blend of data
- Rapid Intensification and weakening continues to be a problem
  - Any sizeable reduction in forecast busts associated with these will somewhat lower the average intensity forecast errors
- The main hope for the future lies in improved dynamical models, coupled with enhanced observations and understanding of the hurricane's inner core
  - Improvements to the dynamical models alone will not be enough
  - Computational advances will be required with increasing complexity and resolution of the dynamical models