Satellite Applications to Hurricane Intensity Forecasting

Christopher J. Slocum - CSU
Kate D. Musgrave, Louie D. Grasso, and Galina Chirokova - CIRA/CSU
Mark DeMaria and John Knaff - NOAA/NESDIS Center for Satellite Applications and Research

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Outline

• Overview of Hurricane Intensity Forecasting Skill
• Statistical Prediction of Intensity from a Consensus Ensemble (SPICE)
• Synthetic IR Imagery Diagnostics
• Improved Maximum Potential Intensity (MPI) with ATMS
• Applications of Eliassen’s Balanced Vortex Model
Atlantic Intensity Error Trends (1990-2012)

NHC Official Average Intensity Errors
Atlantic Basin Tropical Cyclones

Cangialosi and Franklin 2013
2012, Skillful?

Cangialosi and Franklin 2013
NHC Intensity Atlantic and East Pacific Model 48 hr Errors 1989-2012

- Best model improvement significant at 95% level
- Improvements due to statistical-dynamical model (SHIPS and LGEM) improvements and consensus models that combine statistical-dynamical models with HWRF and GFDL
- Statistically significant improvements also seen at 72, 96 and 120 h

DeMaria, Sampson, Knaff, Musgrave, Accepted
Hurricane Forecast Improvement Program (HFIP)

• HFIP is a 10-year program aiming to improve the accuracy of TC forecasts:
  – Reduce average track and intensity errors by 20% in 5 years and 50% in 10 years
  – Increase forecast length from 5 days to 7 days
  – Rapid intensity change:
    • Increase probability of detection to 90% at Day 1 (60% at Day 5)
    • Decrease false alarm ratio to 10% at Day 1 (30% at Day 5)

• For further information on HFIP:
  http://www.hfip.org/

• To view HFIP experimental models and products:
  http://www.hfip.org/products/
Statistical Ensemble

• Logistic Growth Equation Model (LGEM)
• Statistical Hurricane Intensity Prediction Scheme (SHIPS)

• Competitive with dynamical models
• Environment information initialized with
  – GOES imagery at 10.7 microns
  – Dynamic model output [e.i. Global Forecast System (GFS)]
• Fast runtime (under 1 minutes)
**Statistical Prediction of Intensity from a Consensus Ensemble (SPICE or SPC3)**

- Uses a combination of parameters
  - Observed TC intensity and trend
  - GOES imagery at 10.7 microns
  - Model information from GFS, HWRF, GFDL

- Ensemble members combined
  - Two unweighted consensus forecasts (1 DSHP; 1 LGEM)
  - Consensus forecasts used for weighted SPC3 forecast
Results

- HFIP Stream 1.5 SPC3 real-time runs since 2011
  - 5-10% improvement over DSHP and LGEM
  - SPC3 shows improved skill over dynamical models
  - 2012 problematic for SPC3 (issues related to DSHP and LGEM)
Synthetic GOES Imagery

- Created using CRTM from HWRF output
- Compared with observed IR for model diagnostic purposes
- Can be applied to SHIPS and LGEM during the entire forecast period
Real and Synthetic GOES Water Vapor Imagery for Hurricane Isaac

5 Day Forecast Starting 26 Aug 2012 12 UTC
Histograms of Real and Synthetic WV Imagery for All Isaac Forecasts

…………. HWRF Synthetic GOES Channel 3
_______ Real GOES Channel 3
Improving TC Intensity Forecast with Advanced Technology Microwave Sounder on JPSS

- SHIPS and LGEM use Maximum Potential Intensity (MPI)
- Currently MPI is statistically calculated from SST only
- Use ATMS-MIRS T,Q,SLP retrievals together with SST to estimate MPI from ATMS and SST using algorithm by Emanuel (1988), Bister and Emanuel (1998)
- Incorporate improved MPI estimates into LGEM, SHIPS, and Rapid Intensification Index (RII)
Temperature and RH profiles: Leslie (2012)

- Average T, RH between r=00 to 800 km
- Input avg T, RH environmental profiles into Emanuel (1988)
- Replace empirical MPI with ATMS MPI
Balanced Vortex Model Applications

• Assume
  – Inviscid
  – Axisymmetric
  – Quasi-hydrostatic
  – Gradient balanced
  – Stratified
  – Compressible atmosphere
  – $f$-plane

• Can derive 1 of 2 PDEs
  – Geopotential Tendency
  – Transverse Circulation (Eliassen 1951)

• Explain intensity change due to diabatic forcing
  – Fast and simple
  – Model data
  – Aircraft and AMSU
1-D Simplified Geopotential Tendency Equation

\[
N^2 \frac{\partial}{r \partial r} \left( \frac{r}{f^2} \frac{\partial \phi_t}{\partial r} \right) + \left( \frac{\partial}{\partial z} - \frac{1}{H} \right) \frac{\partial \phi_t}{\partial z} = \frac{g}{c_p T_0} \left( \frac{\partial}{\partial z} - \frac{1}{H} \right) Q
\]

\[
\frac{g}{T_0} \hat{T}_t(r) = -\frac{z_T}{\pi} \left( \frac{\pi^2}{z_T^2} + \frac{1}{4H^2} \right) \hat{\phi}_t(r)
\]

From the equations above, we can recover the intensity change.

Musgrave et al. 2012
General Forcing Response
Hurricane Isaac (2012)

- 8/21 to 9/1
- Mostly disorganized
- Max wind spd: 70 kts
- Intensified before making landfall over Louisiana & Mississippi
- 32 radial flight profiles
2-D Successive Over-relaxation

- Transverse circulation via iterative method
- Baroclinic & non-constant static stability
- Response to vertical structure
  - Diabatic heating
  - Tangential velocity
- Inclusion of boundary layer forcing

\[
\frac{\partial}{\partial r} \left( A \frac{\partial (r \psi)}{r \partial r} + B \frac{\partial \psi}{\partial z} \right) + \frac{\partial}{\partial z} \left( B \frac{\partial (r \psi)}{r \partial r} + C \frac{\partial \psi}{\partial z} \right) = \frac{g}{c_p T_0} \frac{\partial Q}{\partial r}
\]
Improvements to using AMSU Rain Rates

• Currently assume
  – All rain deep convective
  – Level of max heating constant
  – No vertical structure based on the baroclinicity

Simpson and Starrett 1995

Schumacher et al. 2004
Conclusions

• Ensemble statistical-dynamical models improve intensity forecasts by 5-10%
• Synthetic IR provides model diagnostic tool and new information for statistical-dynamical models
• ATMS MPI will replace SST MPI
• Balanced vortex model applications provides tool to understand and improve rapid intensity forecasts
References


