Advanced Modeling of Tropical Cyclones
Motivation and Strategy: HFIP

Improve Hurricane Forecasting System (HFS) prediction of intensity and structure

1. Advance modeling system
2. Improve data assimilation
3. Explore better observing strategies
4. Understand physical processes that controls rapid intensity change (intensification and weakening)
NOAA’s Primary Guidance Models

- GFS – T382/64L, 3-DVAR, vortex relocation
- GFDL – movable nested air-sea coupled, inner nest: 9km/42L, specialized vortex initialization
- HWRF – movable nested, air-sea coupled, inner nest: 9km/42L, NH system with data assimilation
HFS: Mesoscale Modeling System

- LAPS
- ENKF
- Standard Initialization
- 3D-Variational Analysis (GSI/NCAR)
- HWRF
- NCEP NH Mesoscale Modeling Core
- NCAR Physics
- NAM Physics
- GFS/GFDL Physics
- Ocean Coupled
- POST Processor
AOML Program Review

2007 Hurricane Season

**TRACK ERRORS (NM)**

- HWRF
- GFDL
- AVN
- CLP

**INTENSITY ERRORS (KTS)**

- HWRF, GFDL and STATISTICAL MODELS

Intensity forecast have not improved in pace with track forecast resolution issue?
High Resolution Mesoscale Modeling Issues

- Improve model component of the HFS
  - Multi-scale problem: resolution & nesting issues (1-3 km scales)
  - Physical processes in a multi-scale environment
    - Representation of Convection
    - Convection -vs- Microphysical processes
    - Numerical issues (horizontal diffusion and damping)
    - ABL Processes (parameterization of BL rolls ?)
    - Sea Spray parameterization
    - Air-sea exchange of momentum and enthalpy
- Improve initialization
  - Data assimilation
- Address Uncertainty
  - Ensembles (multi-model, single model/multiple physics, /initial state, /resolutions, etc.)
Resolution Issues: Structure and Intensity

**HURRICANE DENNIS, 2004**

27-9 km run

9-3 km run

Reflectivity and MSLP

vorticity

**OLUTION MODELING DOWN TO 1-3 KM RESOLUTION OPENS A HOST OF OT**
Physical Processes: Convection

- Changes to convection scheme result in diverse forecasts!
To improve TRACK forecasts:
- Large-scale observations and better assimilation

To improve INTENSITY forecasts:
- Hurricane scale observations to describe 3-D storm structure and data assimilation techniques valid for vortex scale motions
- Feedback to improved track forecasts
Vortex-Scale Data Assimilation

Assimilation of one V ob: 5 m s\(^{-1}\) higher than first guess V (Xuguang Wang, NOAA/CIRES)
Vortex Scale Data Assimilation

- ESRL’s Local Assimilation and Prediction System (LAPS)
- High resolution gridded analysis
- Avoid assumptions on error covariances
Predictability/Uncertainty

From Nguyen et al. 2008
Intensity Research Issues

- Tropical Environment
  - Vortex and trough interactions
  - Shear-vortex interactions
  - Wind and Thermodynamics - Saharan Air Layer

- Vortex-Scale Processes
  - RAINBANDS & EYEWALL REPLACEMENT CYCLES
  - INTERNAL DYNAMICS AND MIXING
  - DRAG AND SURFACE BOUNDARY LAYERS
  - BOUNDARY LAYER ROLLS

- Air Sea Interactions
  - Ocean heat content
  - Wave breaking and sea spray

- Predictability of inner core motions
NOAA cannot meet goals alone!

HFIP Hi-Res Model Workshop

Michalakes, WRF Development Team

Tuleya, Janjic & Black

U. C. Mohanty

Majumdar, Chen & Nolan

Zhang

The Developmental Testbed Center (DTC)
QUESTIONS?
Research Challenges

- Predictability/Uncertainty: Ensembles
- Can model system represent key processes?
  - Large scale wind and moisture structure
  - Convection in vorticity-rich environment
  - Air-sea interface
  - Vortex dynamics
  - Atmospheric boundary layer
  - Upper ocean structure
  - Microphysics/aerosols
- Optimal use of inner core observations