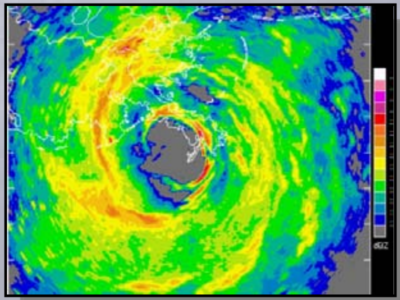
Advanced Modeling of Tropical Cyclones

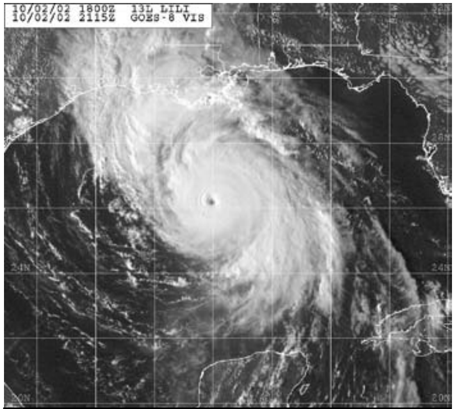


S.G.Gopalakrishnan
AOML Program Review
18-20 March 2008

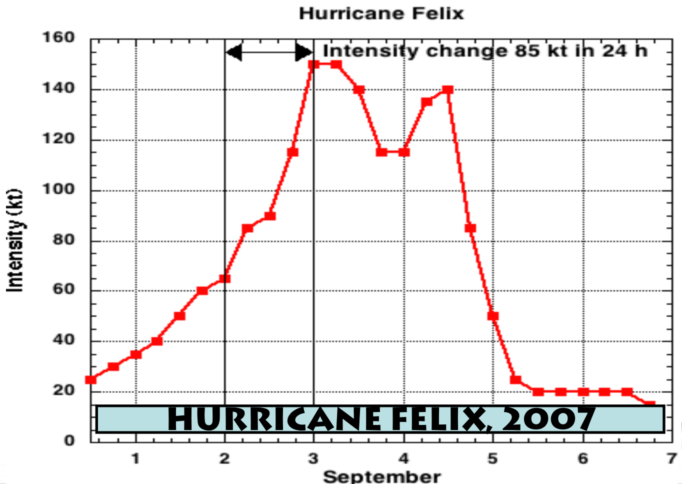
Motivation and Strategy: HFIP

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)



HURRICANE LILI, 2002



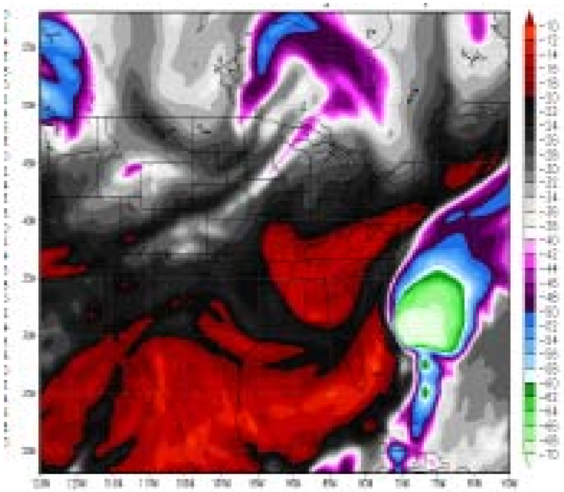
HURRICANE FELIX, 2007

HURRICANE HUMBERTO, 2007

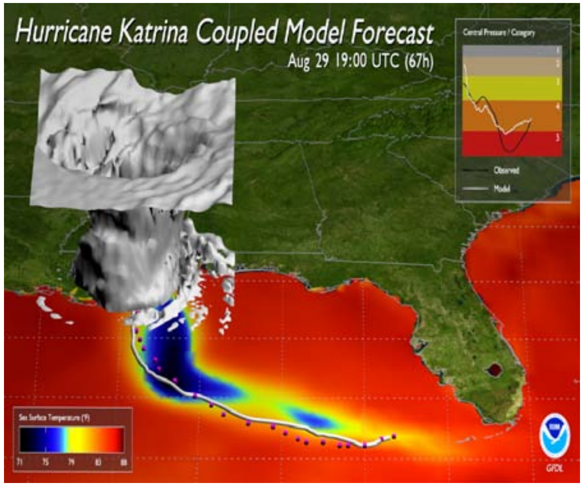
NOAA's Primary Guidance Models

- 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

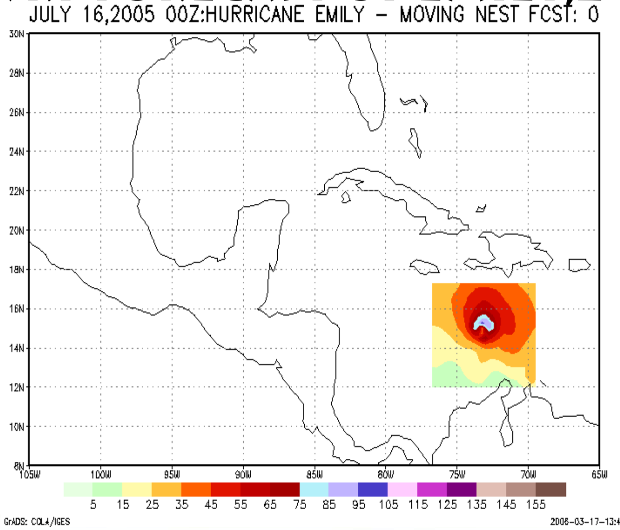
FS: Hurricane Noel, 2007



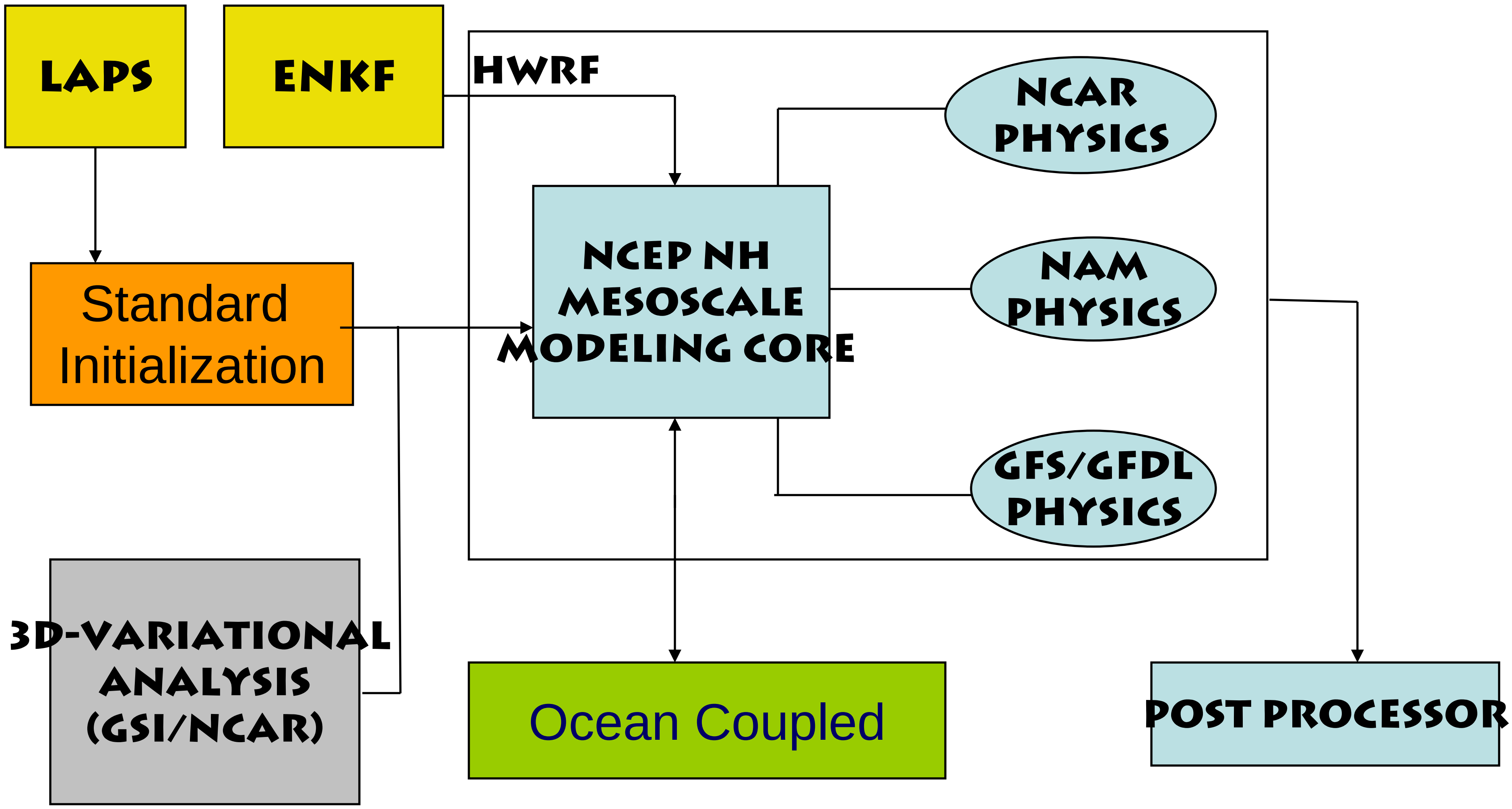
L Forecast of Katrina, 2005



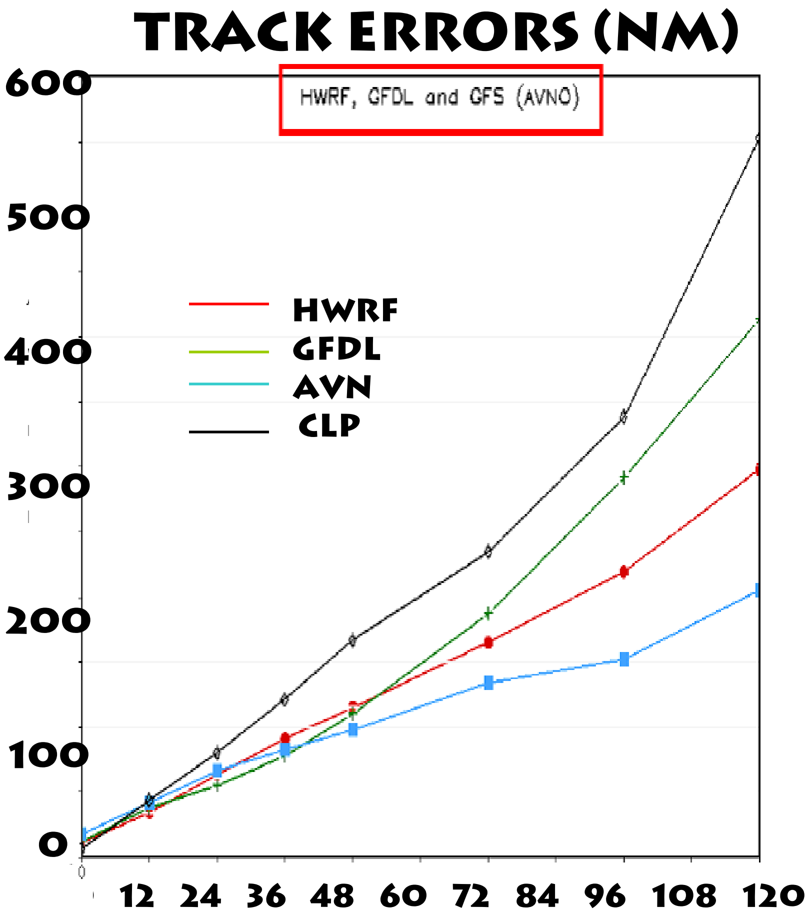
WRF Forecast of Emily, 200

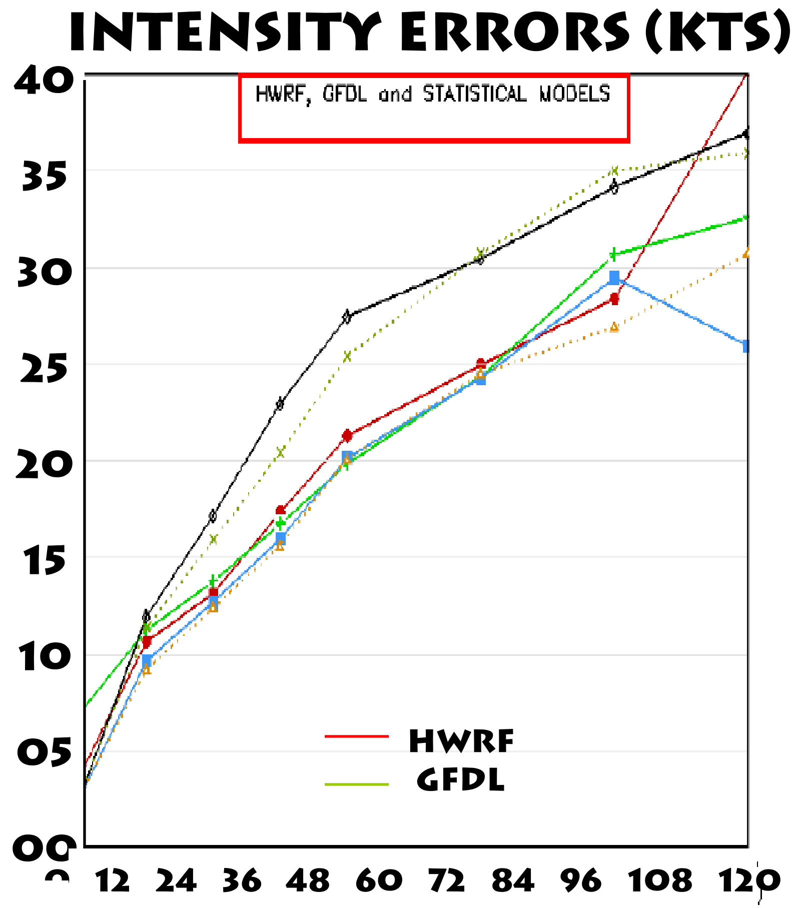


HFS: Mesoscale Modeling System



2007 Hurricane Season





INTENSITY FORECAST HAVE NOT IMPROVED IN PACE WITH TRACK FO
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.)

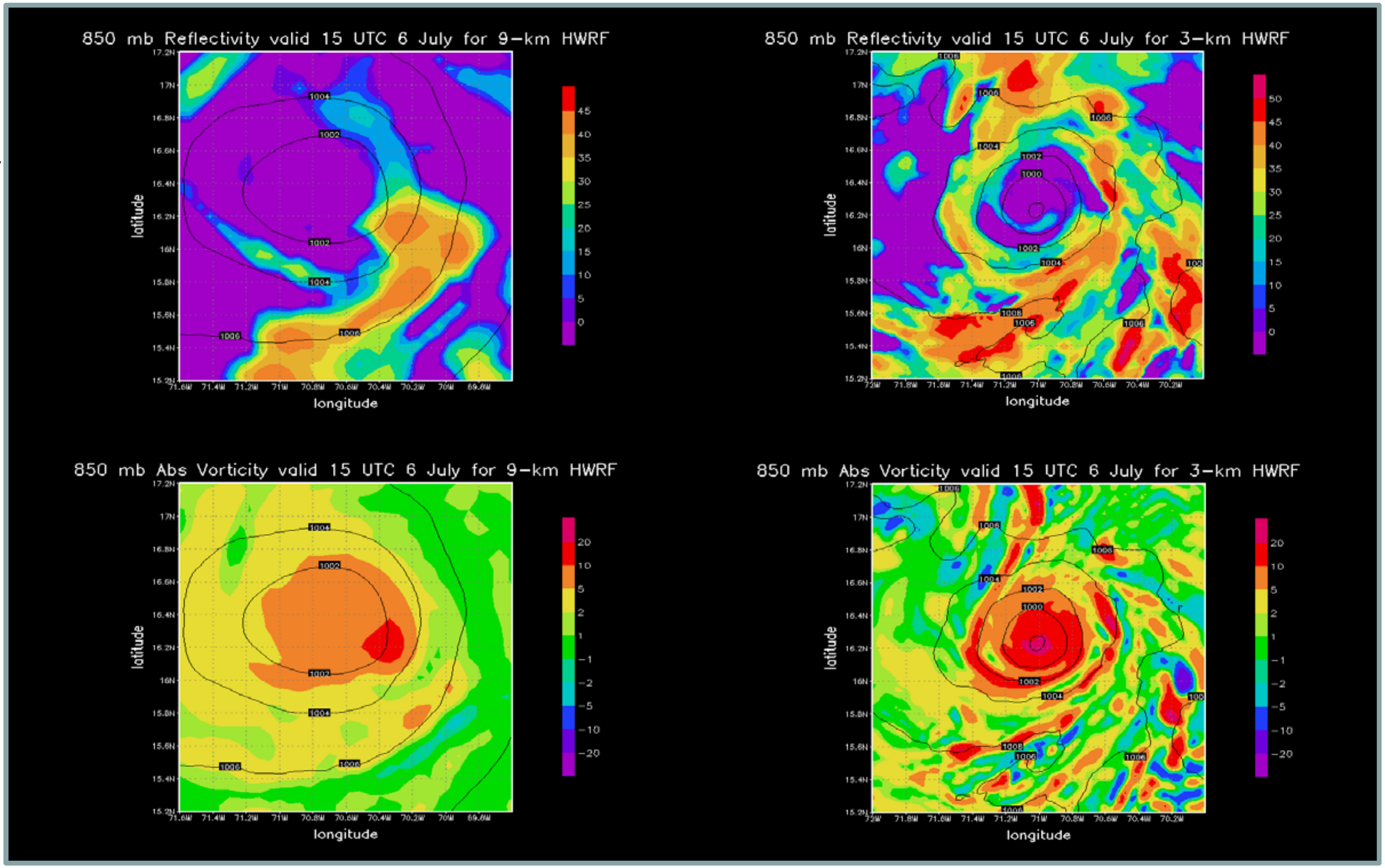
Resolution Issues: Structure and Intensity

HURRICANE DENNIS, 2004

27-9 km run ™ 9-3 km run ™

Reflectivity and MSLP

vorticity

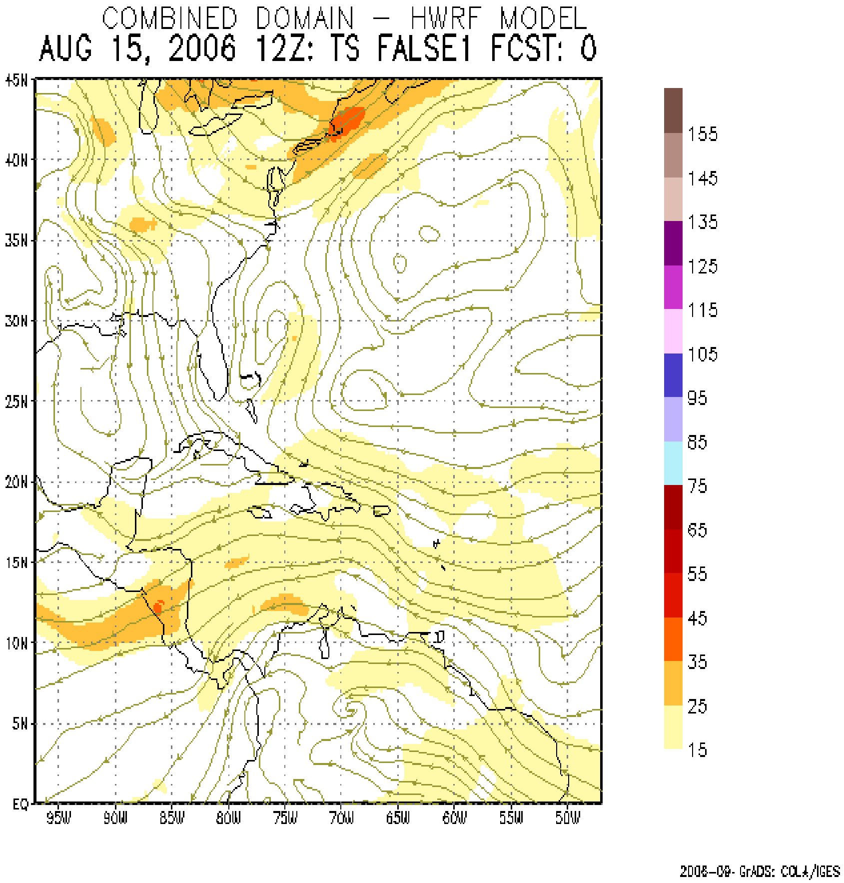


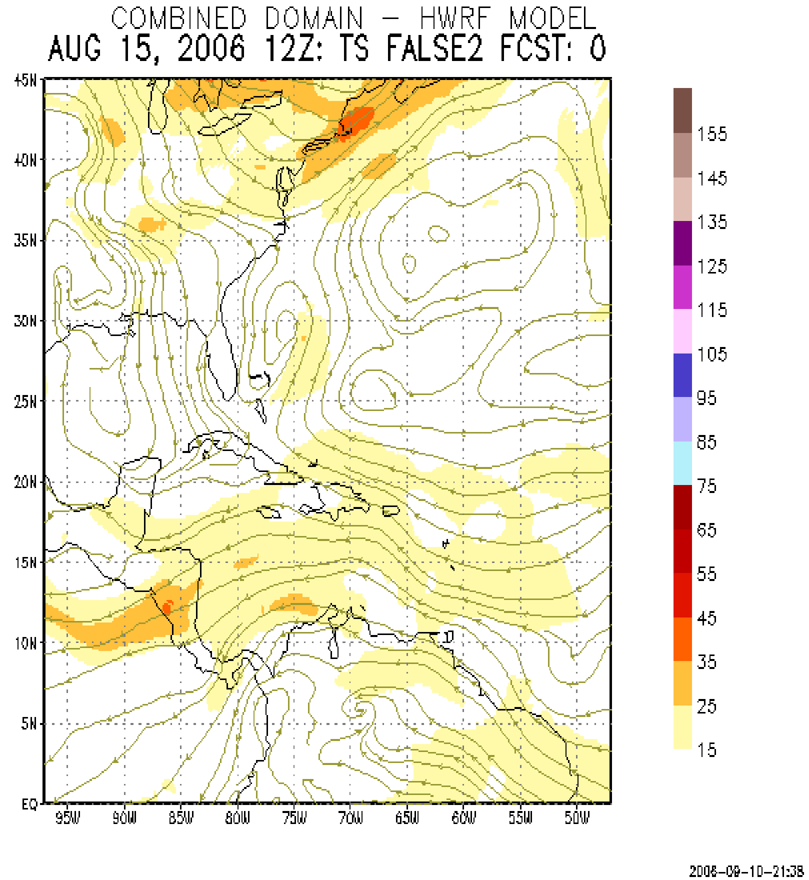
™

OLUTION MODELING DOWN TO 1-3 KM RESOLUTION OPENS A HOST OF OT

Physical Processes: Convection

- Changes to convection scheme result in diverse forecasts!





Data Assimilation

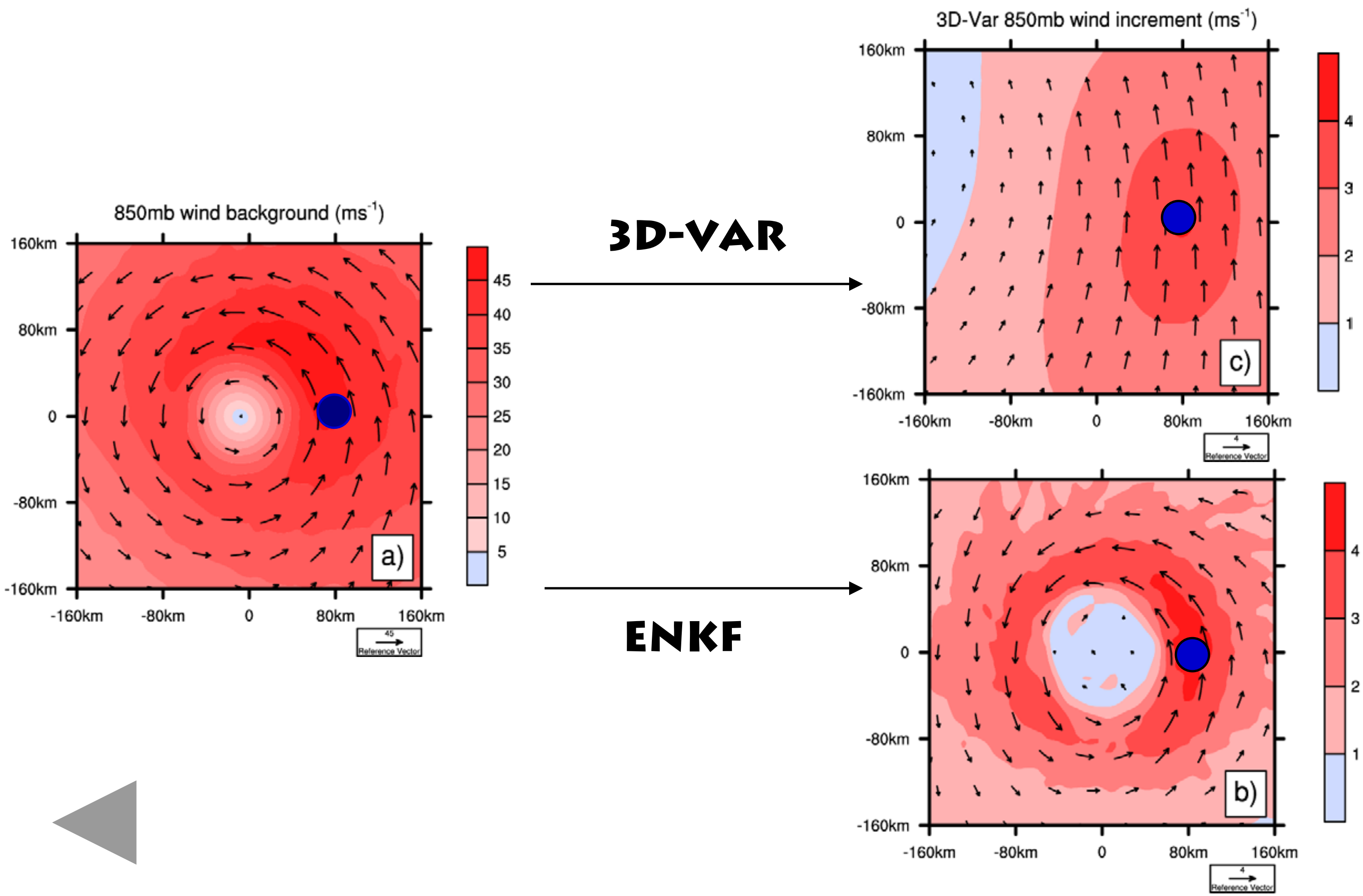
To improve TRACK forecasts:

- 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

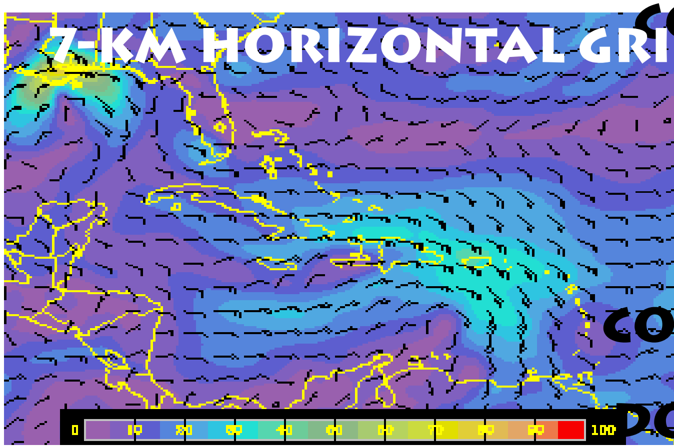
Vortex-Scale Data Assimilation



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

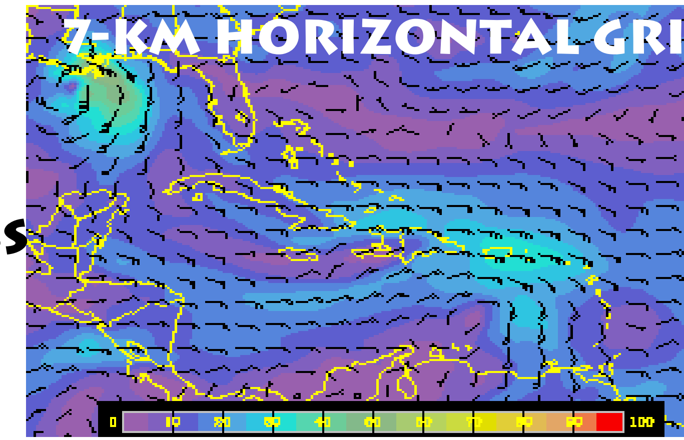
Vortex Scale Data Assimilation

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



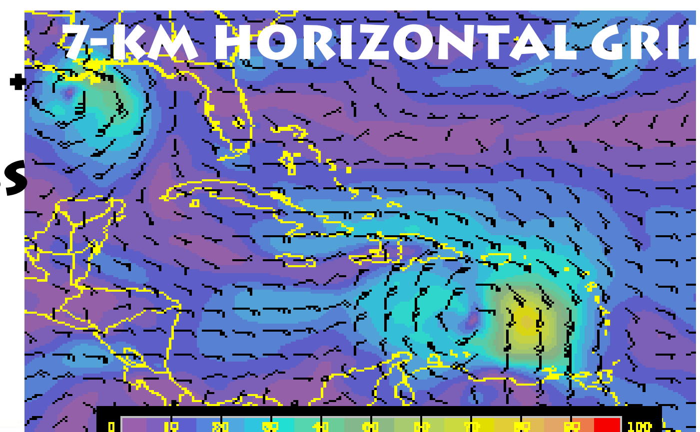
850 HPA GFS ANALYSIS

CONVENTIONAL OBS

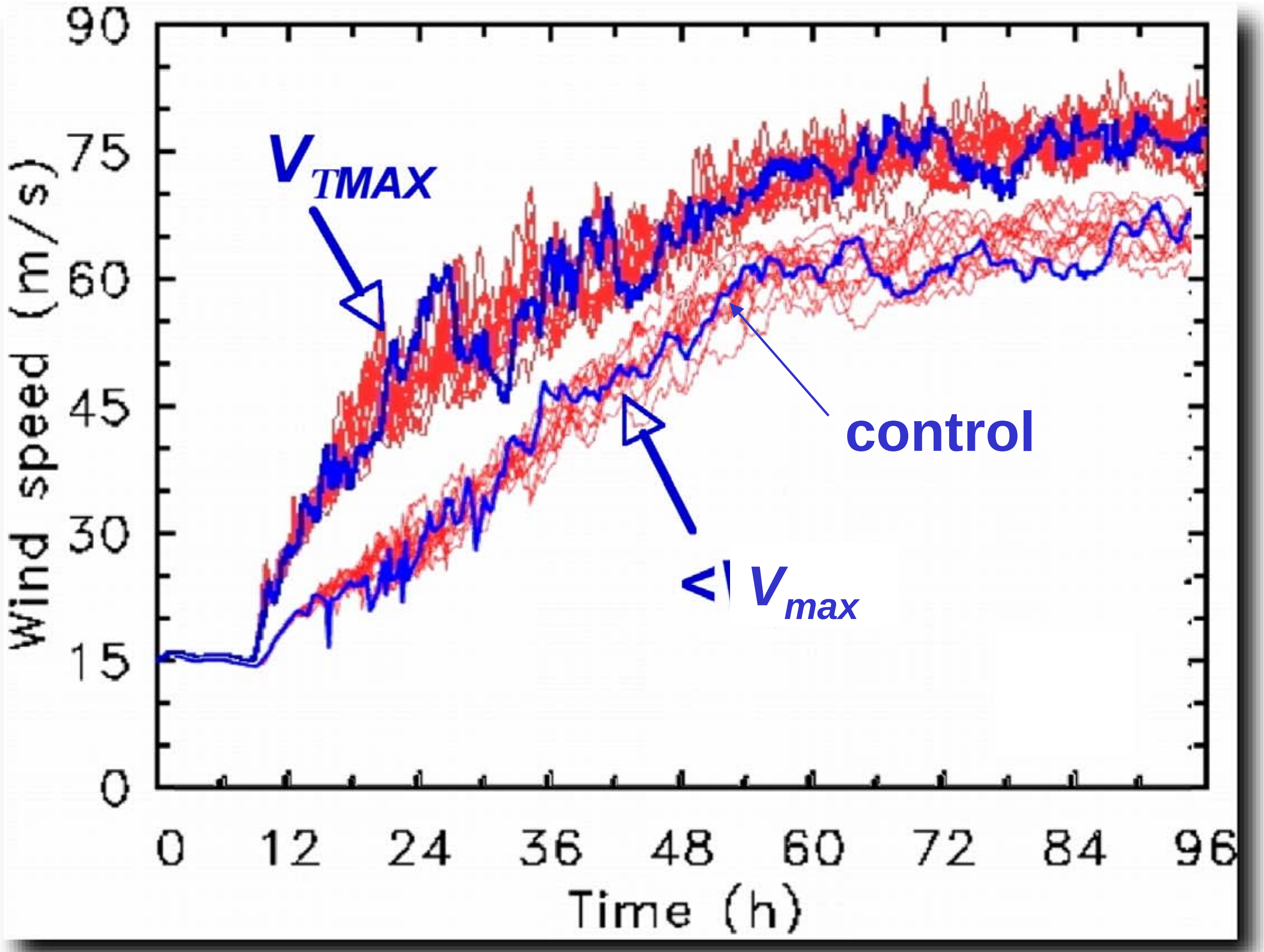


CONVENTIONAL OBS +

DOPPLER RADAR OBS

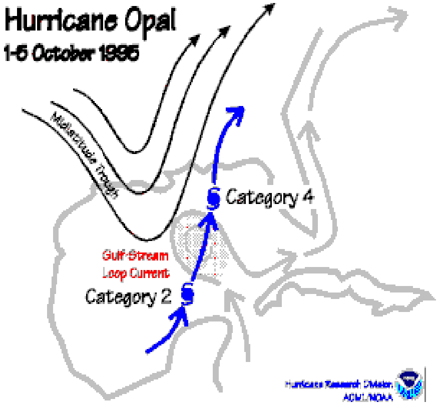


Predictability/Uncertainty



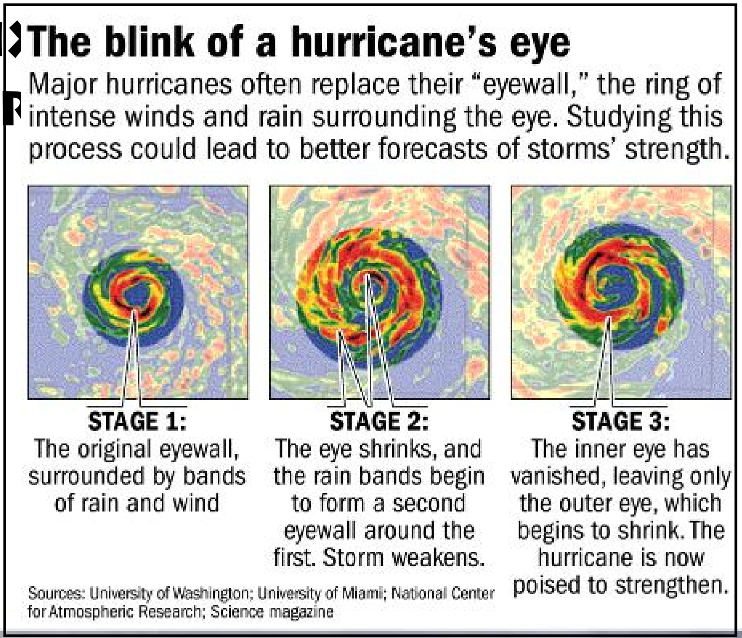
From Nguyen et al. 2008

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 MI**
  - **DRAG AND SURFACE BOUNDAR**
  - **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

The Developmental Testbed Center (DTC)

Tuleya, Janjic & Black

U. C. Mohanty

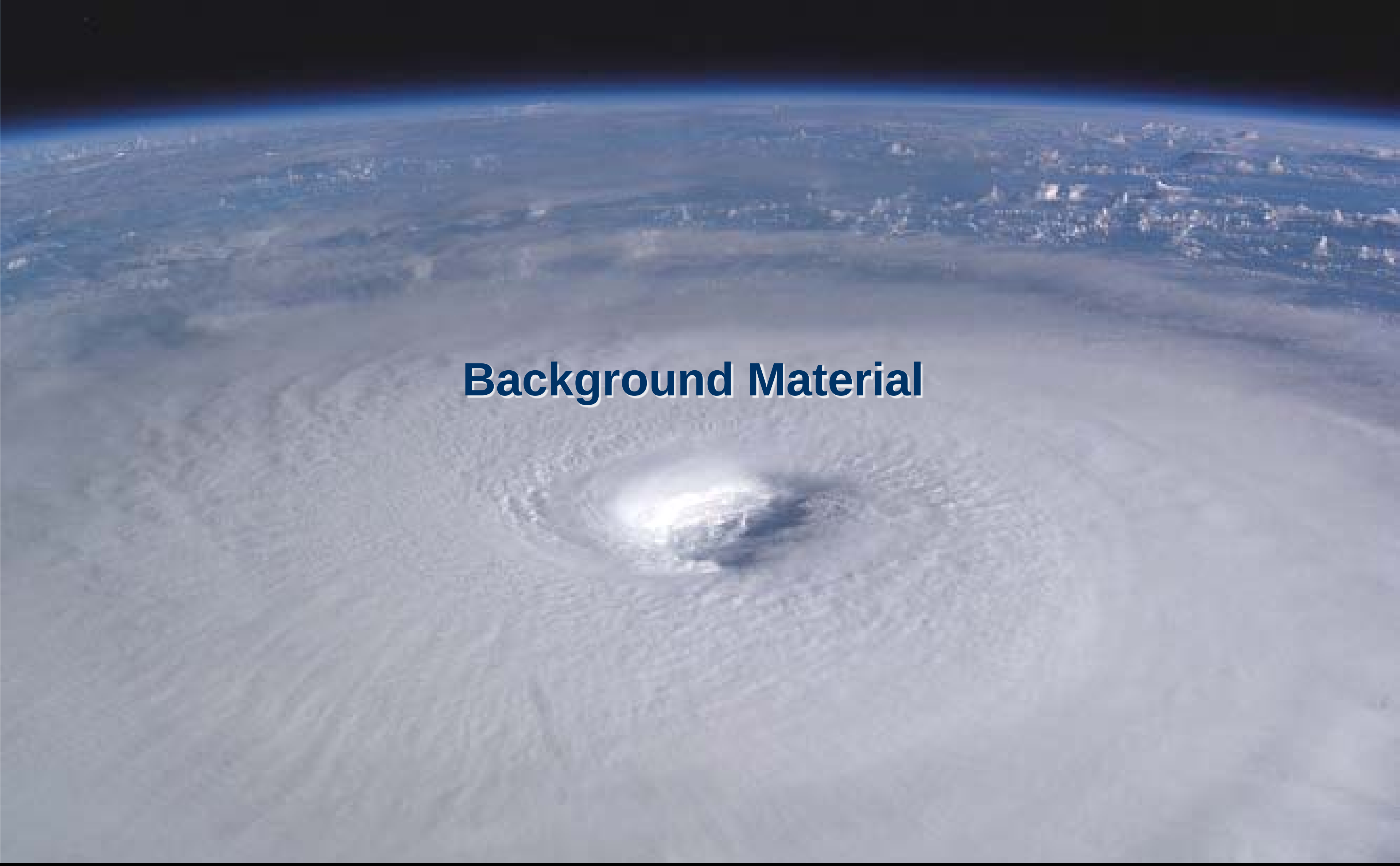
भारतीय प्रौद्योगिकी संस्थान दिल्ली
Indian Institute of Technology Delhi

Majumdar, Chen & Nolan

Zhang


QUESTIONS?

Background Material



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