

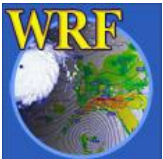
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# AHW (WRF-ARW): (Vortex) Initialization

*Wei Wang*

*NCAR/NESL/MMM*

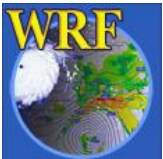
*Hurricane Tutorial, Apr 27 - 29, 2011*



# Introduction

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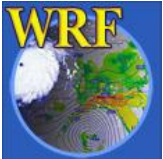
- Vortex initialization is very important to hurricane prediction
- It is a challenging task, hence it is a research area
- ARW supports a few ways to do initialization for hurricanes
  - o Support researchers' need
  - o Flexibility



# ARW (Vortex) Initialization Methods

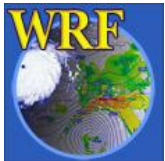
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- Use data from other models directly
- TC bogussing via objective analysis
- TC relocation with previous forecast
- TC relocation and bogussing
- Initialization via obs and analysis nudging
- Initialization via the use of 3DVar
- Initialization via the use of 4DVar
- Initialization via EnKF (see last talk)



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# Use Other Model Data Directly



# Supported Data Sources

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- GFS / FNL (0.5 - 1 degree)
  - o OK during the early stages of storm
  - o May be problematic when the storm becomes intense
  - o Not for intensity
- GFDL / HWRF (9 - 18 km)
  - o Could work for well-developed storms
  - o Imbalance during early forecast hours
- ECMWF Interim Analysis (~ 80 km)
  - o Can benefit from good environmental condition



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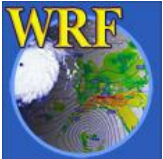
# TC Bogussing via Objective Analysis



# Method

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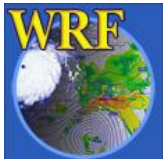
- Based on technique of objective analysis (e.g. Cressman)
- ARW V3.1 supports such an program: *obsgrid.exe*
  - In addition to normal synoptic observations, bogus data either generated from a Rankine vortex or soundings extracted from previous model forecast
- For detailed description of *obsgrid* program, please see Chapter 7 of the User's Guide



# Pros and Cons

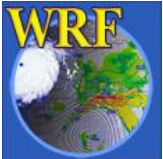
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- Advantage:
  - o Easy to use
- Disadvantage:
  - o Relocation may be important
  - o Spread of data is artificial
  - o No dynamic and thermodynamic constrains



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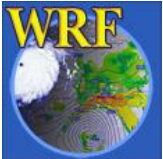
# TC Relocation Using Previous Model Forecast



# TC Relocation

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- Based on the assumption that model simulated vortex has reasonable structure
- The model vortex is lifted from a previous forecast, and moved to the current, correct location
- Works better on pressure level data
- May adjust vortex profile after relocation
- Papers by Liu et al. (1997), Tenerelli et al. (2001)



# Pros and Cons

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- Advantage:
  - o Easy to implement, especially with moving nest
- Disadvantage:
  - o Blending of vortex environment may be problematic
  - o May have problem with storm relocating from ocean to land or vice versa
- Tools available to do this:
  - o *p\_interp*: put model data on pressure levels



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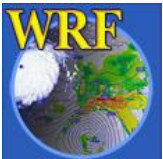
# TC Relocation and Bogussing



# Method

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- ARW V3.1 supports a simple TC bogussing scheme: *tc.exe*
- The scheme is adapted from MM5:
  - Detect and remove existing vortex
  - Bogus in a Rankine vortex based on best track TC info
  - Works on pressure level data after WPS and before real.exe
- For details, please refer to Chapter 10 of the ARW User's Guide

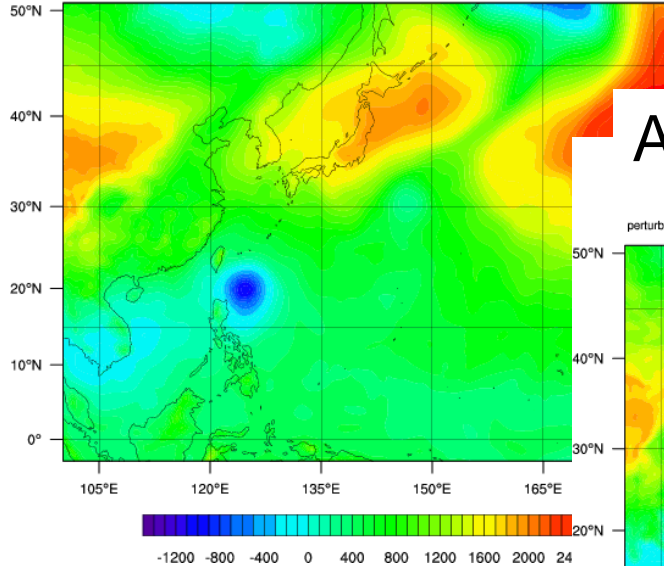


# An Example for Sinlaku (2008)

Control

Init: 2008-09-10\_00:00:00  
Valid: 2008-09-10\_00:00:00

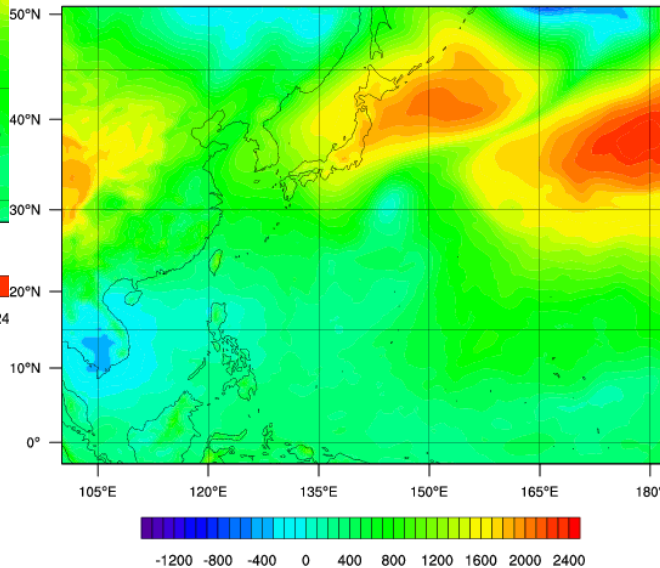
perturbation dry air mass in column (Pa)



Original

After Vortex Removal

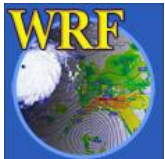
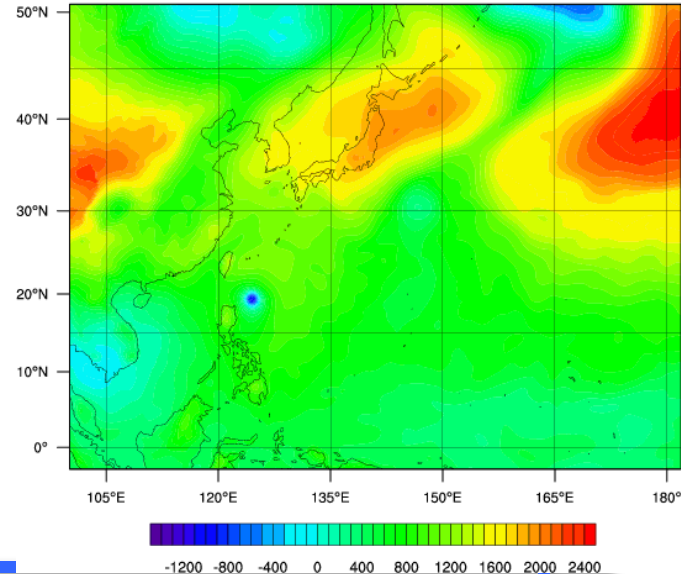
perturbation dry air mass in column (Pa)



Bogus After Bogussing

3-10\_00:00:00  
3-10\_00:00:00

perturbation dry air mass in column (Pa)

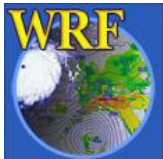


*(From Gill and Fredrick)*

# Pros and Cons

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- Advantage:
  - o Easy to do
  - o Provide a placeholder for improved bogussing technique
- Disadvantage:
  - o Artificial vortex data
  - o Imbalance with model solution



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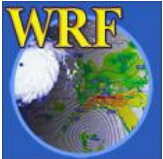
# Initialization via Observation and Analysis Nudging



# Method

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- Based on observation and grid-analysis nudging technique [Stauffer and Seaman (1990, 1991), Liu et al. (2008)]
- Available as runtime option in ARW
- Aimed at providing good analysis for the storm environment
- Can be successful when doing it continuously - hence model generated storm can be recycled



# Pros and Cons

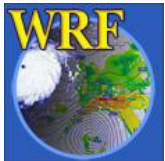
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- Advantage:
  - o Easy to implement
  - o Use of model
  - o Nudging technique is being improved
- Disadvantage:
  - o May not work over part of the ocean where conventional data is sparse
  - o Nudging term can be arbitrary



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# TC Bogussing Using 3DVar

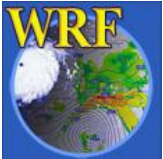


# Method

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- Three-dimensional data assimilation (3DVar) produces an analysis by combining a background forecast and observations through an iterative minimization procedure of a prescribed cost function
- The information about background and observation errors is used to spread data
- Can assimilate many types observations

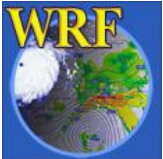
*Ref: Barker et al. (2004)*

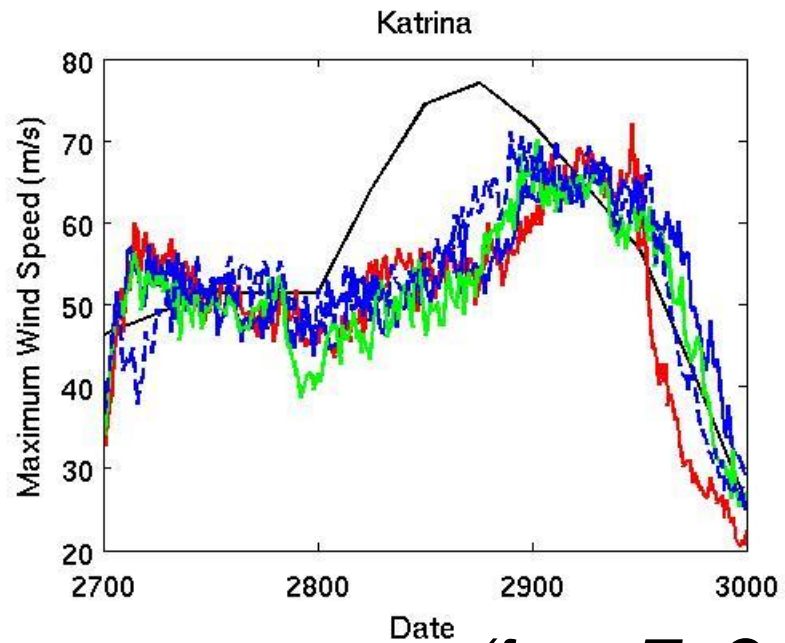
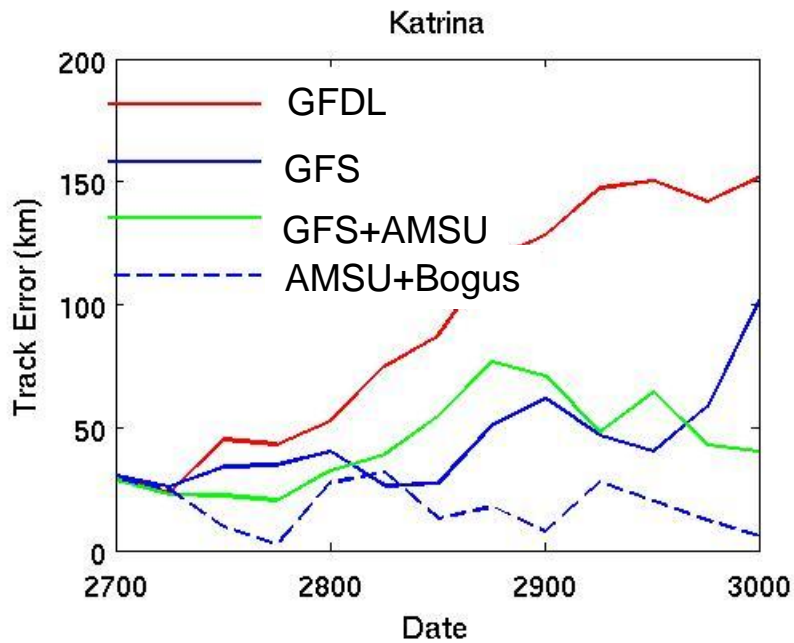
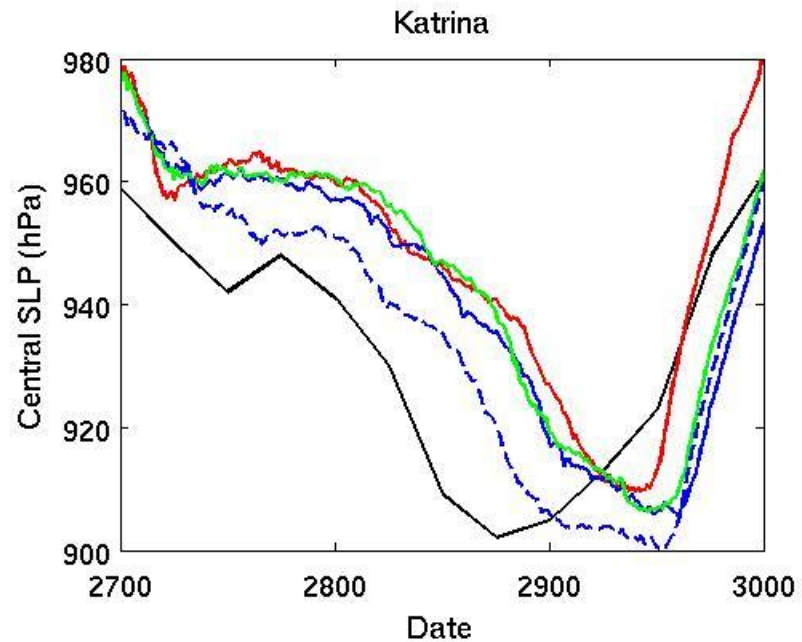
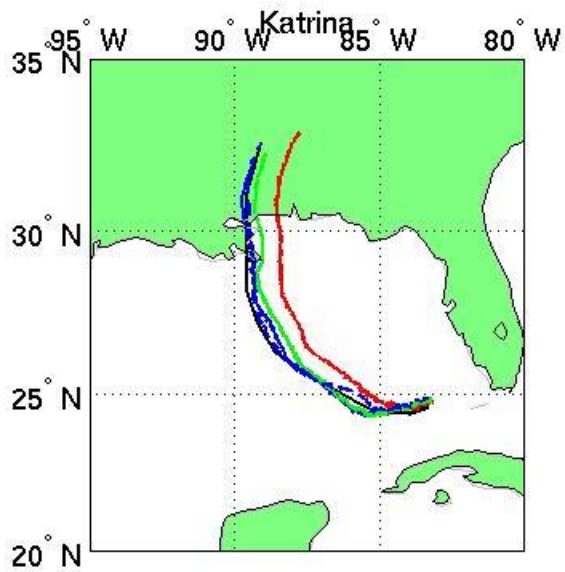


# Method

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- When 3DVar is applied to TC initialization, one can do one of two things:
  - Improving environmental conditions by assimilating conventional as well as remote sensed data (including radiance)
  - In addition, bogus data may be used. Relocation needed
- Cycling may be used to retain characteristics of the model vortex



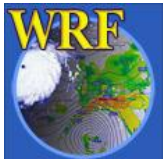


(from Z.-Q. Liu)

# Pros and Cons

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- Advantage:
  - o Good mathematical base
  - o Computationally efficient (relative to other more sophisticated techniques)
- Disadvantage:
  - o Background error covariance not changing with time and flow regime, and can be problematic for TC
  - o Single time-level can be limiting
  - o May take time to learn to use the technique well



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# TC Initialization Using 4DVar

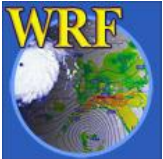


# Method

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- The difference between 3DVar and four-dimensional (4DVar) data assimilation is the use of a numerical forecast model
- The added time dimension provides flow-dependent information
- Can use observation in a time window

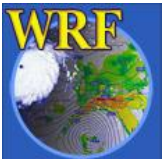
*Ref: Huang et al. (2009)*



# An Example:

## WRF 3D/4D-Var for Katrina 2005

- WRF Domains : D1-D3 with 40.5km, 13.5km, 4.5 km grids and 35 vertical levels; Data assimilations only applied on D1
- Forecasts: 96-h deterministic run with D1, D2, D3 (two-way nested and D3 movable) initialized from 00Z August 26 2005 with various ICs
- Data assimilated: Doppler radial velocity (err=3m/s) from KMAX and KBYX during 00~03Z August 26 2005

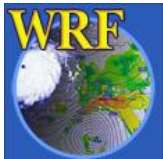
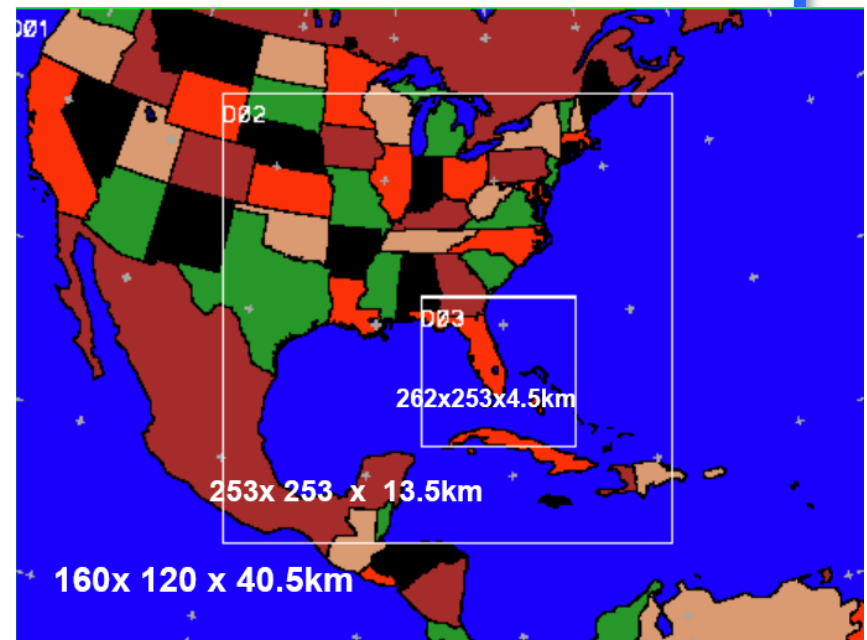


# An Example

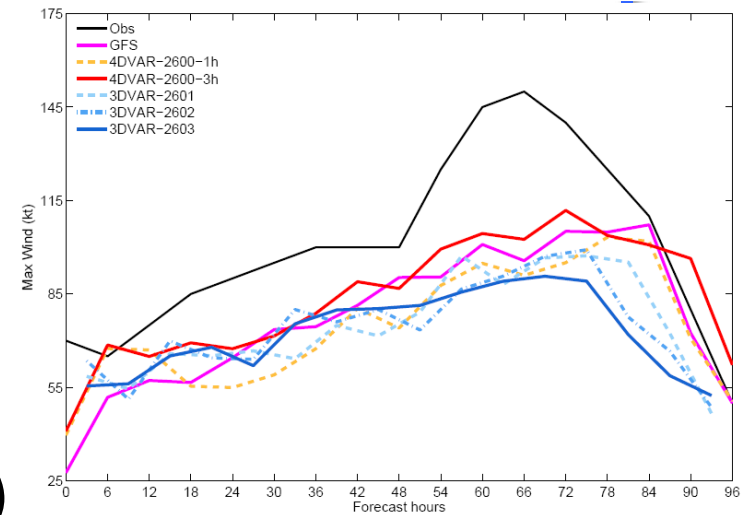
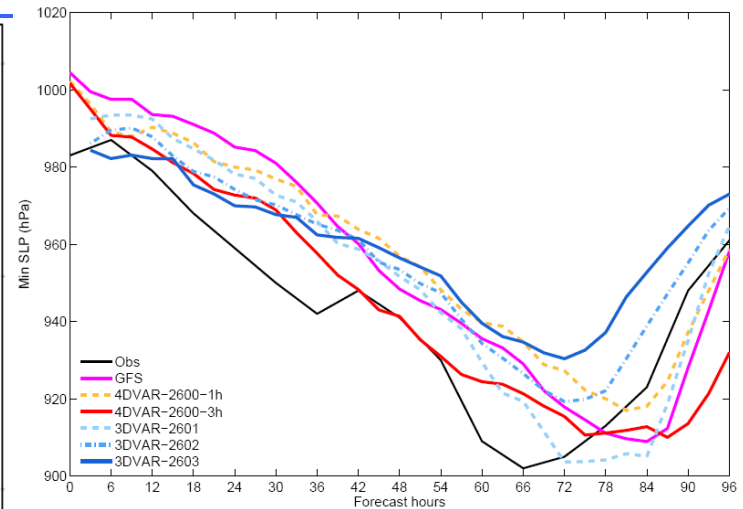
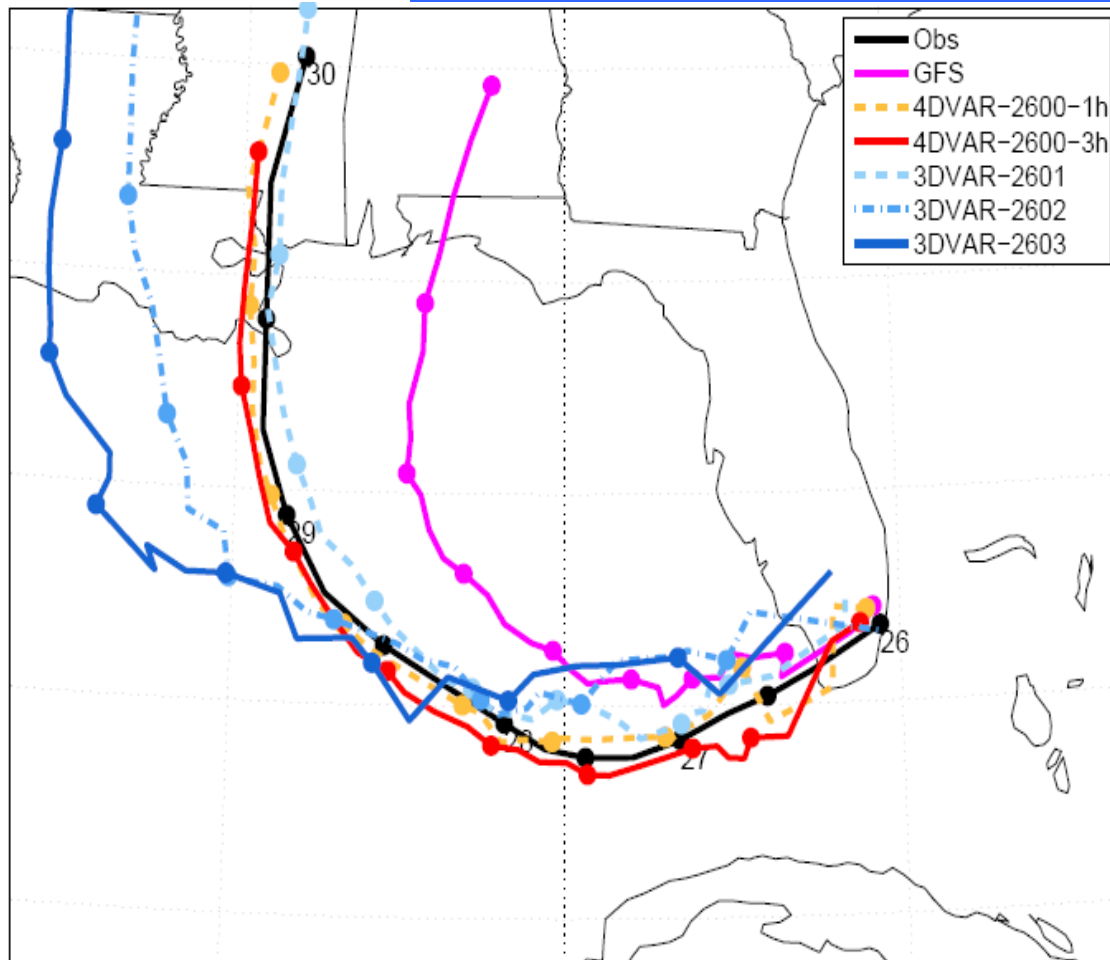
Experiments:

- a) Control run with GFS-IC
- b) 4DVAR with 1-h and 3-h window
- c) Successive 3DVAR with 1-h interval at 01Z, 02Z and 03Z respectively

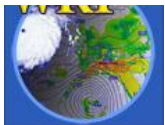
*(from M. Zhang of PSU)*



# Track and Intensity Forecast on Aug 26, 2005



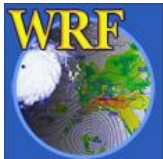
(from M. Zhang)



# Pros and Cons

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- Advantage:
  - o Good mathematical base
  - o Use of model for dynamic and thermodynamic constrain
  - o Flow dependent
- Disadvantage:
  - o Expensive technique
  - o Probably long learning curve



# In Summary...

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- TC initialization still a challenge
- Experimentation is needed for large sample of cases: a technique working for one case may not work for another
- The need in research and operation may be different
- The results of using various methods seem to suggest that some kind of cycling method tends to perform better

