Joint Hurricane Testbed: Mid-year Progress Report, Year 2

Dynamic Initialization to Improve Tropical Cyclone Intensity and Structure Forecasts

Principle Investigator: Chi-Sann Liou
Naval Research Laboratory, Monterey, CA

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1. Background

Diabatic digital filtering (DDF) initialization has been successfully developed and tested for tropical cyclone initialization in the first year of this project using Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS®[1]) as a development tool. The tasks of the second year are to implement the DDF initialization into hurricane Weather Research and Forecasting (HWRF) model and evaluate and adjust the dynamic Initialization procedure.

Digital filter is a very selective low-pass filter. It filters out unbalanced high-frequency components from initial conditions through weighted inverse Fourier transform

$$\tilde{f}_n = \sum_{k=-N}^{k=N} h_k w_k f_{n-k} , \qquad (1)$$

where $\tilde{f}_n$ is the filtered field, f_{n-k} is the original field, $h_k = \frac{\sin k\theta_{cutoff}\Delta t}{k\pi}$ is the filtering weight with cutoff angular frequency θ_{cutoff} , and w_k is the window function to reduce Gibbs oscillations. For diabatic digital filtering, the field f_{n-k} is obtained by diabatic integration from $-\frac{1}{2}T_{cutoff}$ to $\frac{1}{2}T_{cutoff}$ with the initial condition at $-\frac{1}{2}T_{cutoff}$ obtained by backward adiabatic integration (Fig. 1). With a very efficient Dolph-Chebyshev window, we have demonstrated in the first year that a 2-hour cutoff period (i.e., T_{cutoff} =2 hours) is sufficient to balance initial conditions for tropical cyclone forecast. This relative short cutoff period not only reduces the overhead of the dynamic initialization but also simplifies boundary condition treatments in the initialization integration. The -1 hour to +1 hour time integration allows us to use fixed lateral boundary conditions for the outermost mesh and fixed surface boundary conditions for all meshes during the initialization integration.

2. Work in Progress

(a) Task 1: *Implement the diabatic digital filtering into HWRF*

The implementation of DDF initialization into HWRF involves with the following modeling works:

(1) prepare a FORTRAN-90 module that includes all new routines for DDF initialization,

(2) add new arrays and namelist variables for DDF to the NMM registry file,

(3) write a driver routine that handles how the HWRF forecast model will be executed during the different phases of the initialization integration,

[1] COAMPS is a trademark of Naval Research Laboratory

(4) develop an algorithm that is compatible with HWRF time integration to control DDF time integration and write a DDF time integration controller, and

(5) integrate the DDF time integration controller into HWRF forecast model.

In order to consult the proposed works with the HWRF team, a trip to NCEP/EMC was made at the end of July 2006. In that visit, we came up with a consensus that we should use ESMF clock utility routines to handle DDF time integration and isolate DDF interface to HWRF at one place by inserting a DDF control routine either in subroutine "integrate" right before the call to "solve_interface" or in subroutine "wrf_run" right before the call to "integrate". To accommodate the timing control for DDF integration, we need to add a new "ESMF_clock" variable, "ddf_clock", to the definition of data type "domain" in module_domain. The starttime, stoptime, and timestep attributes of "ddf_clock" should be properly prepared by using the ESMF clock utility routines before they are used in the DDF controller routine to control the DDF time integration. Coding works of (1), (2) and (3) has been completed and developing works of (4) and (5) are underway. A test program has been written and exercised to get familiar with ESMF clock routines and test the DDF time integration control using the attributes of "ddf_clock". Furthermore, a trimmed version of HWRF forecast model has been created that includes only the data flow of HWRF without actual calculation for model forecast. The trimmed model is used as a tool in testing the DDF time integration and determining the best place to insert the DDF integration in HWRF. These tests are currently performed at a local IBM computer at FNMOC even though computer accounts have been established for this project at NCEP computers. Network security limitations make local computers be a more productive choice at this stage of coding development.

(b) Task 2: *Test, evaluate, and adjust the implement dynamic initialization in COAMPS and HWRF*

We have continued testing, evaluating, and adjusting the DDF dynamic initialization for tropical cyclone forecast in COAMPS. In past few months, we have concentrated on testing the DDF initialization for high resolution (Δx=5km) moving grids. The DDF initialization works well and removes unbalanced components in initial conditions for the high resolution tropical cyclone forecast (Fig. 2). In the case shown in Fig. 2, although the DDF initialized tropical cyclone circulation is weaker than the analyzed circulation, the initialized cyclone circulation is closer to the observed circulation (Vmax=130kt) and the follow-up cyclone forecast matches better with observed cyclone tendency. This indicates that the OI analysis used in the current study gives a too strong and unbalanced tropical cyclone circulation for the 5km resolution grids in this case. The error statistics of track forecast shows that the DDF initialization gives significant improvement to 45km and 15km resolution track forecasts, but less significant improvement to 5km resolution track forecast (Fig. 3). Very large initial corrections made by the DDF initialization to unbalanced high resolution tropical cyclone analysis (as shown in Fig. 2) is considered as the cause of lacking improvement in the 5km resolution forecast. We will test the DDF initialization with to-be-operational 3D-Var analysis for COAMPS in the near future.

In evaluating the DDF initialized forecast, we found that in the early forecast of the outermost mesh (mesh-1) suffers with large adjustments in lateral boundary zones, same as that without initialization, even after the DDF initialization. After several numerical experiments we found that if the fixed boundary condition treatment for mesh-1 grids in the initialization integration is handled by unchanged boundary conditions rather than unchanged boundary zone forecasts, the large adjustment will also be removed by the DDF initialization as well (Fig.4). This revision gives slightly improvement in the tropical cyclone track forecast (not shown).

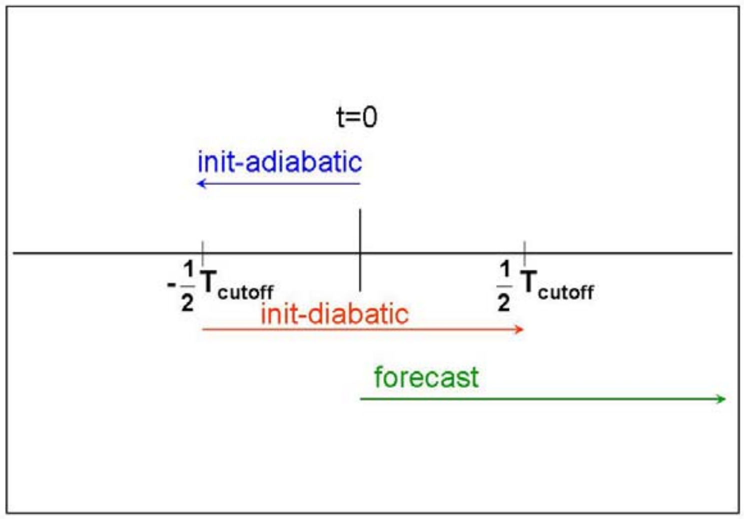

Fig 1. Schematic diagram of diabatic digital filtering time initializations.

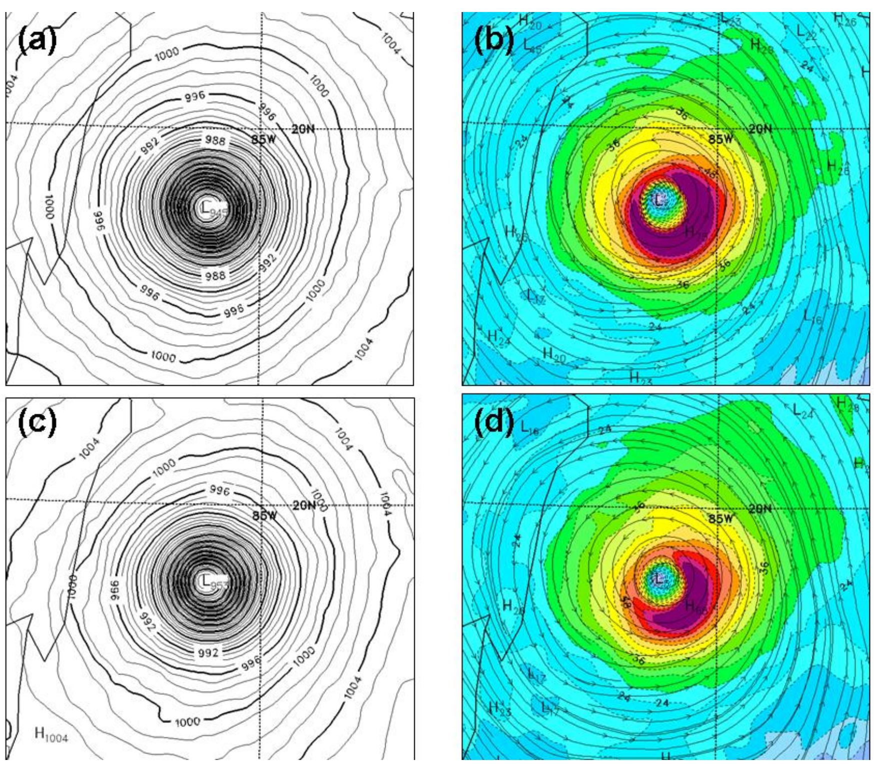

Fig 2. Five-km resolution (a), (c) Sea-level pressure and (b), (d) 850 mb wind of hurricane Wilma at 0000 UTC 21 October 2005 before and after DDF initialization, respectively.

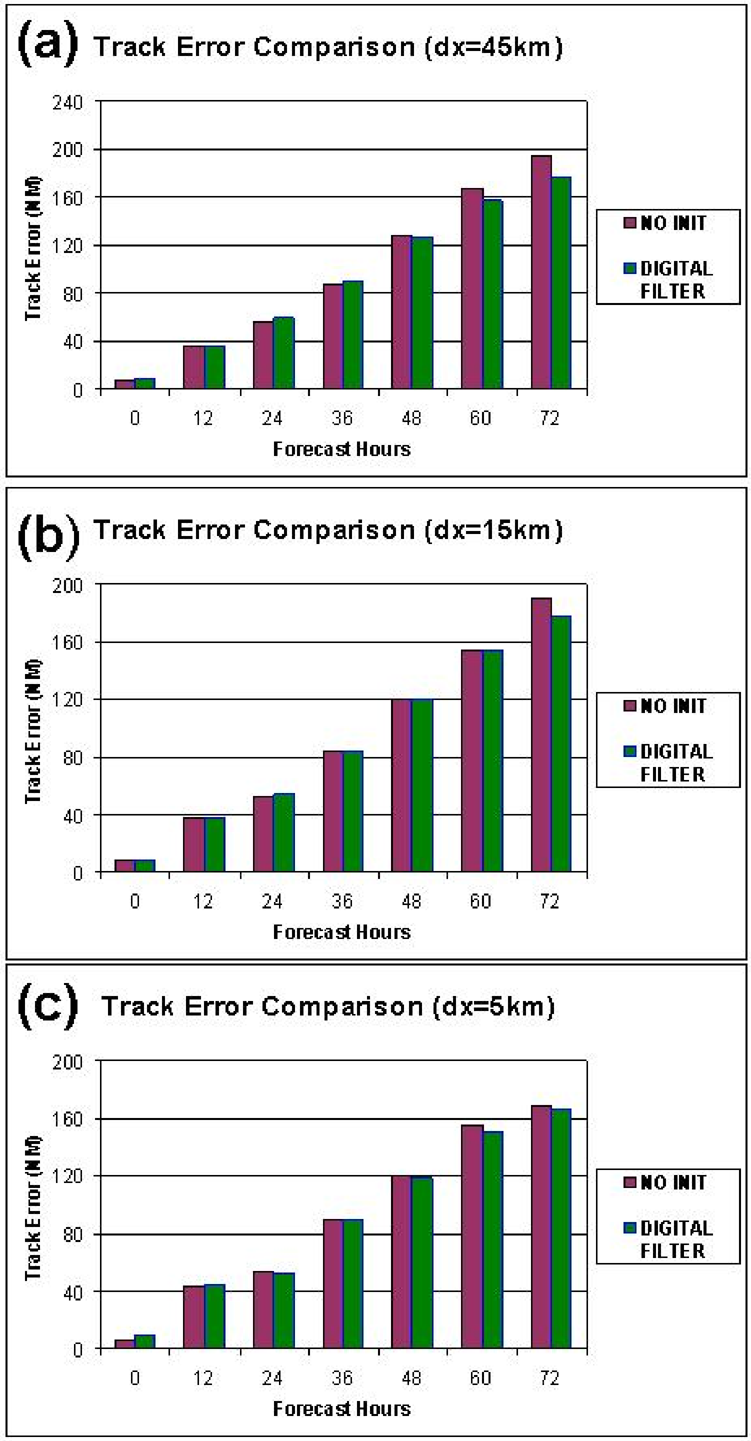

Fig 3. Track error statistics comparison with (green) and without DDF (purple) for (a) 45-km resolution mesh-1, (b) 15-km resolution mesh-2 and (3) 5-km resolution mesh-3.

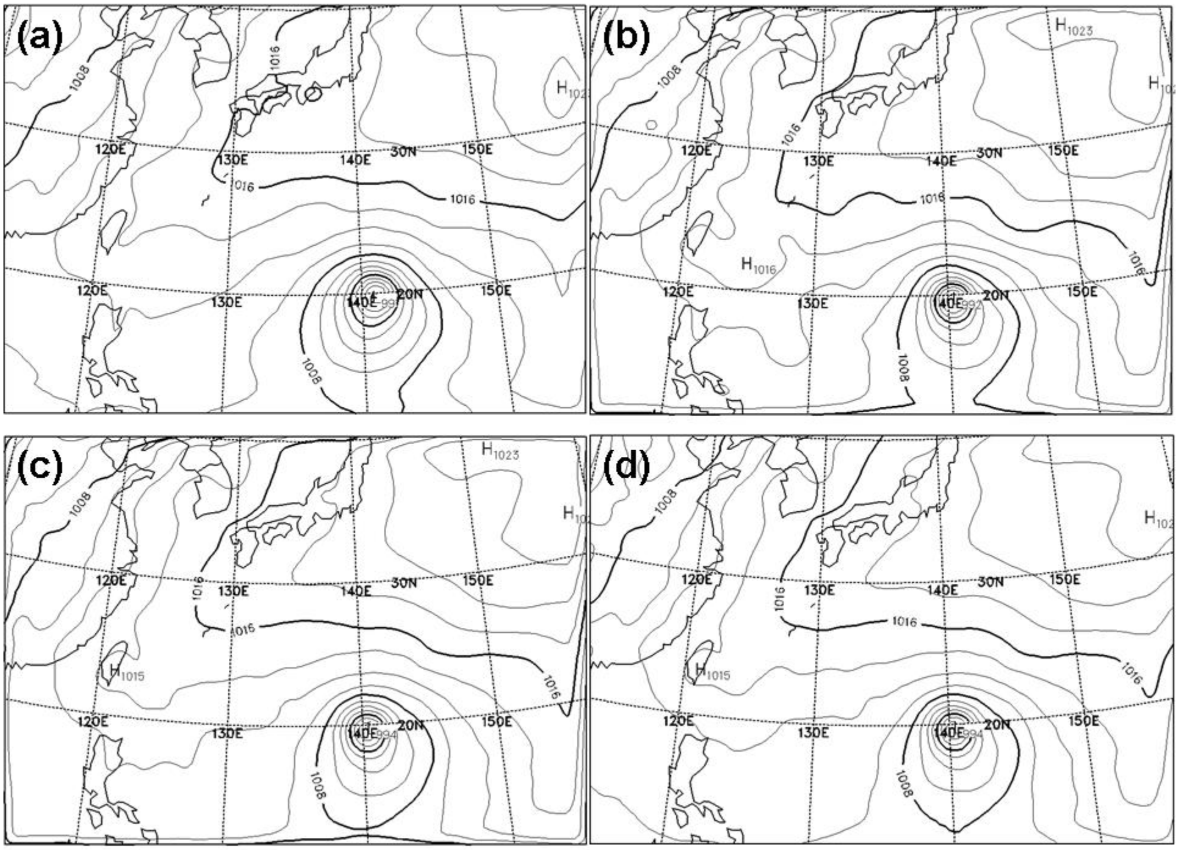

Fig 4. Seal-level pressure of the 45-km outermost mesh for typhoon Haitang at 1200 UTC 14 July 2005 (a) analysis, (b) 1h forecast without DDF, (c) 1h forecast with DDF and fixed boundary zone forecasts, and (d) 1h forecast with DDF and fixed boundary conditions.