8.4 AN INTRODUCTION TO THE NCAR-AIRDAT OPERATIONAL TAMDAR-ENHANCED RTFDDA-WRF

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1. INTRODUCTION

During the summer of 2009, AirDat and NCAR jointly implemented an operational CONUS-scale cloud-resolvable (4-km grid) Real-Time Four Dimensional Data Assimilation (RTFDDA) and forecasting system, known as the NCAR-AirDat RTFDDA-WRF. RTFDDA was originally developed jointly by NCAR and the US Army Test and Evaluation Command (ATEC). The operational NCAR-AirDat RTFDDA-WRF is built upon the Weather Research and Forecasting (WRF) ARW-core. RTFDDA uses a Newtonian relaxation observational nudging data assimilation engine, which allows the model to more effectively assimilate measurements from fixed-location platforms, as well as continuous, moving platforms such as the Tropospheric Airborne Meteorological Data Reporting (TAMDAR) sensor, than a 3D data assimilation scheme currently used by many operational centers.

The TAMDAR sensor measures humidity, pressure, temperature, winds aloft, icing, and turbulence, along with the corresponding location, time, and altitude from built-in GPS. These observations are transmitted in real time to a ground-based network operations center via a global satellite network. The sensor network has been expanded to cover Alaska, the CONUS, and Mexico. Additional expansion into the Caribbean with begin this year. The TAMDAR temperature, winds and humidity reports are continuously assimilated into the NCAR-AirDat RTFDDA-WRF modeling system. The operational modeling system cold-starts once a week, and produces 4 forecast cycles a day with each cycle producing a 6 h analysis and 72 h forecast from the dynamically consistent and cloud "spun-up" analysis produced by 4D continuous data assimilation.

Preliminary analyses of the operational forecasts during the late 2009 summer and fall will be presented. Advantages of using high-resolution WRF and FDDA of the TAMDAR data for the short-range forecasting for summer convection over the currently available operational products will be reported. The ongoing studies focus on the various degrees of forecast impacts provided by the additional airlines currently being equipped with TAMDAR sensors, and refine the data assimilation settings for optimal use of the TAMDAR data.

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2. MODEL CONFIGURATION

Over the last year, AirDat and NCAR have worked together to implement a version of RTFDDA-WRF (3.1.1), which is an "observation-nudging" FDDA–based method built around the WRF-ARW core. This system is able to assimilate synoptic and asynoptic observational data sets, including various surface data (e.g., METAR, SYNOP, SPECI, ship, buoy, QuikScat seawinds, mesonets, etc.), and various upper-air observations (e.g., TEMP, PILOT, wind profilers, aircrafts (TAMDAR), satellite winds, dropsondes, radiometer profilers, RAOBS, Doppler radar VAD winds, etc.).

Several recent improvements have been made to the observation nudging scheme, including the ability to assimilate multi-level upper-air observations using vertical coherency principles. Additional improvements have been made to the terrain-dependent nudging weight corrections, including a ray-searching scheme, which eliminates the influence of an observation to a model grid-point if the two sites are physically separated by a significant mountain ridge or a deep valley.

RTFDDA "observation-nudging" is built for multi-scale mesoscale data assimilation. The multi-scale features are represented by differing influence radii for different grids and employs a revised "double-scan" approach.

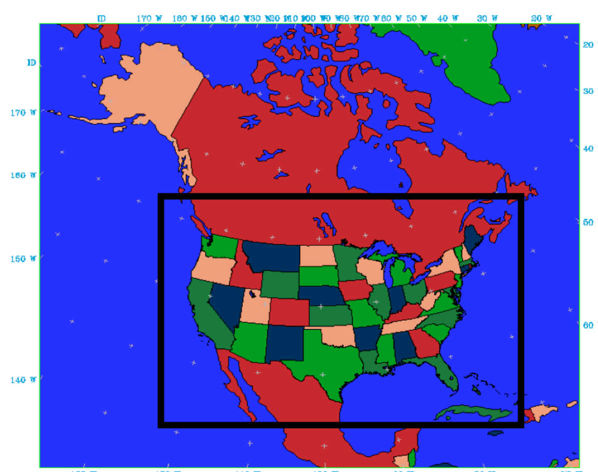

Fig. 1. The operational North America NCAR-AirDat RTFDDA-WRF grid configuration.

Research is currently underway to develop an analysis nudging technique, which can be used to take advantage of a 3DVAR analysis that assimilates nondirect remote sensing observations. This technique is at the center of the proposed "Hybrid" RTFDDA-WRF system, which AirDat and NCAR expect to be implementing over the first 6 months of 2010.

The outer domain (Fig. 1.) features a grid spacing of 12 km with 74 vertical sigma levels, of which the highest concentration reside in the mixed layer, as well as near the jet stream level. The inner domain has a 4 km grid spacing that also has 74 vertical levels.

Once the "Hybrid" RTFDDA-WRF system is released, an Atlantic basin tropical grid will also be configured to run in real time from July through October. The physics and dynamics configuration will be slightly different from the North American grid to better represent tropical dynamics.

The proposed tropical RTFDDA-WRF configuration is discussed below. The tropical grid will have an initial grid spacing of 12 km with 74 vertical sigma levels. Zhang and Wang (2003) conclude that using higher vertical resolution, especially within the mixed layer, a thin surface layer, and smaller numerical time step generally produce more realistic simulations of tropical cyclone strength and inner core structure. These results are being investigated on the time and scale of the proposed modeling configuration.

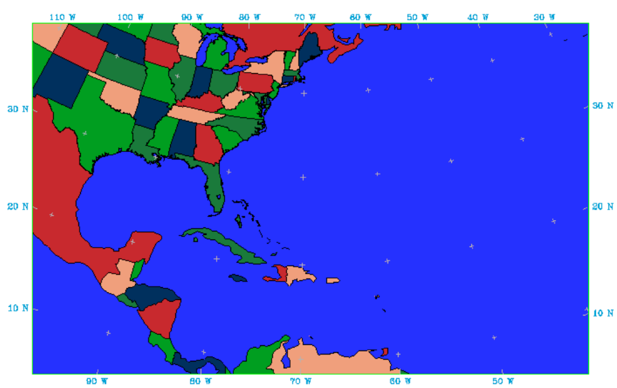

Fig. 2. The tropical NCAR-AirDat RTFDDA-WRF grid configuration.

The RTFDDA-WRF has the ability to use all the synoptic and asynoptic (e.g., TAMDAR) observations. It assigns a weight to each observation according to its time, location, and quality. This mitigates dynamics and cloud/precipitation spin-up problems that exist in all cold-start operational models.

The initial RTFDDA-WRF system began cycling on 6-h intervals to 72 hours in late July 2009. The domain configuration was (is) a 12 km North American grid, with a single nested 4 km CONUS scale grid. While the exact runtimes varied from cycle to cycle, the average runtime per forecast cycle was roughly 5.75 hours. The initial configuration used the Lin microphysics scheme, the Kain-Fritch cumulus scheme (no CP for the 4 km), the YSU boundary layer, and the NOAH LSM. The radiation was handled by the RRTM (longwave) and Dudhia (shortwave). The general performance of the configuration was very good, but there were several adjustments and upgrades that have been (and will be) implemented over the past (next) 6 months.

3. RECENT MODIFICATIONS

An adjustment was made to the adaptive time step along the lateral boundaries to address a minor error in the relaxation zone along the boundaries of the outer 12 km grid. It is along these boundaries that the model brings in the forecast tendencies from the NCEP Global (GFS) model. This update is to ensure that the lateral boundaries remain numerically accurate and stable. In order to achieve the 72-h forecasts within the 6 h time window, the model employs an adaptive time step function that is more computationally efficient than the static time step functions; however, a small inconsistency was discovered in the code that may have caused a slight degradation in the final analysis of each cycle. This was also corrected.

Several of the data sets that are assimilated into the RTFDDA-WRF analysis are observed on height levels. Height-based data assimilation code was added to replace the conversion of the height levels to pressure levels, which allows the model to assimilate the observations directly on the native observation levels. This upgrade will have the greatest impact on wind profiler data assimilation, and should produce a slight improvement in the low-level wind forecasts.

The initial installation of RTFDDA-WRF assimilated sea surface temperatures (SST) based on the NCEP standard 40 km grid. This is not the most ideal SST data to assimilate when running the model at very high resolutions, so the upgrade to the latest high resolution Real-time Global Sea Surface Temperature analysis (RTG SST HR) product from the Polar Center at NCEP was installed (Gemmill et al. 2007). This is a high quality, 9 km (0.083 degree) SST composite that should improve the forecasts of storm system tracks, strengths, and also the surface temperature and wind forecasts in coastal regions.

In late August 2009, the WRF-ARW executables were upgraded to latest release version from NCAR (Version 3.1.1). With the exception of a few minor formatting issues, this process was seamless. The final adjustment for 2009 was to change the microphysics scheme from Lin to the Morrison two-moment scheme (Morrison et al. 2009). The Morrison scheme has double-moment relations for rain, ice, snow and graupel, which allows for increased definition in high-resolution severe convective forecasts, and in high-impact winter precipitation events. In addition to the prediction of the mixing ratios of the hydrometeor species, this scheme also predicts the number concentration. Improvements in cloud cover and surface temperatures have been seen with this scheme. While computationally more intensive than the Lin scheme, time was saved through some additional pre-processing optimization, so the runtime was offset.

4. FUTURE UPGRADES

There are several upgrades planned for the first part of 2010. A Kalman Filter-based bias correction algorithm will be applied during the post processing to correct systematic forecast errors. This method has been shown to substantially improve forecasts for 2-m temperatures and 10-m winds. The other major planned upgrade for 2010 is the Hybrid based assimilation, which will allow the combination of the best attributes of both variational assimilation, and RTFDDA-based nudging assimilation. The benefits will include expanding the outer 12 km domain, and greatly improving tropical cyclone and ocean forecasts. This assimilation technique provides the capability of assimilating the full suite of satellite-based radiance and sounder data, which is critical to increasing the forecast accuracy and skill in data-sparse regions.

5. ACKNOWLEDGMENTS

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