5A.2 MAINTAINING A LOCAL DATA INTEGRATION SYSTEM IN SUPPORT OF WEATHER FORECAST OPERATIONS

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1. INTRODUCTION

Since 2000, both the National Weather Service in Melbourne, FL (NWS MLB) and the Spaceflight Meteorology Group (SMG) at Johnson Space Center in Houston, TX have used a local data integration system (LDIS) as part of their forecast and warning operations. The original LDIS was developed by NASA's Applied Meteorology Unit (AMU; Bauman et al, 2004) in 1998 (Manobianco and Case 1998) and has undergone subsequent improvements. Each has benefited from three-dimensional (3-D) analyses that are delivered to forecasters every 15 minutes across the peninsula of Florida. The intent is to generate products that enhance short-range weather forecasts issued in support of NWS MLB and SMG operational requirements within East Central Florida. The current LDIS uses the Advanced Regional Prediction System (ARPS) Data Analysis System (ADAS) package as its core, which integrates a wide variety of national, regional, and local observational data sets. It assimilates all available real-time data within its domain and is run at a finer spatial and temporal resolution than current national- or regional-scale analysis packages. As such, it provides local forecasters with a more comprehensive understanding of evolving fine-scale weather features.

Recent efforts have been undertaken to update the LDIS through the formal tasking process of the AMU. The goals include upgrading LDIS with the latest version of ADAS, incorporating new sources of observational data, and making adjustments to shell scripts written to govern the system. Operationally, these upgrades will result in more accurate depictions of the current local environment to help with short-range weather forecasting applications, while also offering an improved initialization for local versions of the Weather Research and Forecasting (WRF) model.

2. ADAS MODELING SYSTEM

The ADAS modeling system (Brewster 1996) was developed by the University of Oklahoma to assimilate a variety of observed data that could then be initialized by the ARPS numerical weather prediction (NWP) model. ADAS has two main components. The first is a Bratseth objective analysis scheme that evaluates pressure, wind, potential temperature, and specific humidity. The second component is a 3-D cloud analysis scheme that is used for the hot-start initialization (Zhang et al. 1998). The ADAS cloud analysis is designed to create consistency with all data and the typical meteorology of clouds by using surface observations of cloud cover and height, satellite data, and radar data to determine the cloud cover, cloud liquid and ice water, cloud type, rain/snow/hail mixing ratios, icing severity, in-cloud vertical velocity, cloud base and top, and cloud ceiling (Case et al. 2002; Zhang et al. 1998; Brewster 2002).

3. LDIS CONFIGURATION

A series of scripts run the complete modeling system, each script accessing a stand-alone file that includes all user-configurable parameters. These parameters can be modified to meet the needs of the end user. Input parameters include domain information such as horizontal and vertical grid spacing, domain location, as well as model integration time, directory structure, and other program specific information. The suite of scripts consists of the preprocessing step, main model integration, and the post-processing step. The preprocessing step prepares the two-dimensional (2-D) terrain and surface characteristics data sets, interpolates the external forecast grids to the ARPS model grid that supplies the background fields to ADAS, and prepares the objective analysis for model initialization. The model integration step runs the model to create the forecast, and the post-processing step outputs the desired products.

3.1. *Pre-Processing*

The program ARPSTRN creates the 2-D terrain datasets, using a bi-linear interpolation scheme to analyze data. It currently supports four raw terrain data sets to create the 2-D fields: 1°x1° (~110 km), 5'x5'(~10km), 30"x30" (~1km), and 3"x3" (US coverage only). The program ARPSSFC creates the 2-D vegetation type, soil type, and normalized difference vegetation index (NDVI) datasets and then maps the data to the specified ARPS grid. The 3-D background or first-guess field for the model initialization is created in the program EXT2ARPS. A larger-scale external model provides the values for the initial fields. EXT2ARPS extracts these fields and interpolates them to the ARPS grid. The resultant data sets can then be used in the ADAS analysis.

There are two methods available to quality control the data within the ADAS analysis program. The first pre-analyzes surface data by comparing observations with each other. Data are rejected if they differ significantly from neighboring observations. Observations are also compared to the background field interpolated to the observation site and are rejected if there are significant differences. The second is a manual method of excluding data at specified surface stations. ADAS includes a blacklist file to filter out those stations that regularly have instrument failures or unrepresentative observations.

The ADAS analysis program interpolates observations onto the ARPS grid, combining the observed information with the background field produced by EXT2ARPS. The observed data must first be converted into a format acceptable by ADAS. ADAS will ingest four types of observed data:

1) Single-level observations such as surface and individual aircraft observations,
2) Multiple-level or upper-air observations, such as rawinsondes, wind tower data, and wind profilers,
3) Raw Doppler radar observations, and
4) Radar-retrievals.

ADAS also ingests satellite data that is remapped from satellite-observed pixels to the ARPS grid. This data is then used in the ADAS cloud analysis that was described in Section 2.

3.2. *Model Integration*

This study used the WRF model for the main model integration. The WRF numerical weather modeling system consists of two dynamical cores, the Advanced Research WRF (ARW) and the Non-hydrostatic Mesoscale Model (NMM). The ARW core was developed primarily at the National Center for Atmospheric Research (NCAR) while the NMM was developed at the National Centers for Environmental Prediction (NCEP). The work described in this report employed the WRF Environmental Modeling System (EMS) software, which was developed by the NWS Science Operations Officer (SOO) Science and Training Resource Center (STRC). A benefit of using the WRF EMS is that it incorporates both dynamical cores into a single end-to-end forecasting model (Rozumalski 2006). The software consists of pre-compiled programs that are easy to install and run. The WRF EMS contains the full physics options available for the ARW and NMM cores, however, the physics options for the NMM are more limited than for the ARW.

3.3. *Post-Processing*

The WRF EMS software post-processes the WRF model forecasts from either the NMM or ARW cores. The forecast files are output in Network Common Data Form (NetCDF) format on native model levels. The post-process step converts these files to GRIdded Binary (GRIB) format with additional fields and interpolated to either height or isobaric coordinates.

4. REAL-TIME DATA INGEST

The LDIS is set up to ingest a variety of observational data. For this study, data ingested include

- Level II Weather Surveillance Radar-1988 Doppler (WSR-88D) data from six Florida radars,
- Geostationary Operational Environmental Satellites (GOES) visible and infrared satellite imagery,
- Florida surface and upper air observations from NOAA's Earth System Research

Laboratory/Global Systems Division /Meteorological Assimilation Data Ingest System (MADIS), and

- Kennedy Space Center (KSC)/Cape Canaveral Air Force Station (CCAFS) wind tower network data.

The Level II WSR-88D data contains full volume scans of reflectivity at a resolution of 1° by 1 km, radial velocity at 1° by 0.25 km, and spectrum width data at 1° by 0.25 km (Fulton et al. 1998). These data are available every 4 to 6 minutes. The GOES-12 visible imagery is available at a 1 km horizontal resolution every 15 minutes, and the infrared imagery is available at a 4 km horizontal resolution also every 15 minutes. Both visible and infrared imagery provide brightness temperatures to the analysis packages. Both surface and upper air observations from the MADIS system are available throughout Florida. Measured variables include u- and v-wind components, temperature, dewpoint temperature, pressure, and sea surface temperature. The KSC/CCAFS wind tower network provides measurements of wind speed and direction, temperature, dewpoint temperature, and pressure and are available within 35 km of KSC/CCAFS.

As stated in Section 3, output from larger-scale models is used to provide the values for the initial fields. In this study, the Rapid Update Cycle (RUC) was used for the background initial conditions and the North American Mesoscale (NAM) model was used for boundary conditions. The WRF ARW model simulation was run at a 4 km horizontal grid spacing over the Florida peninsula and adjacent coastal waters with 40 irregularly spaced, vertical sigma levels.

5. COLD SEASON CASE STUDY

On the morning of 10 December 2009, a cold front approached Florida from the northwest and a moderate southwest flow prevailed ahead of the front across the peninsula. Surface temperatures exceeded 70°F across most of the peninsula in the early morning, with similar dewpoint temperatures. NWS MLB forecasters indicated the biggest challenge for this day would be forecasting the temperatures due to the competing influences of the diurnal temperature cycle and the passage of a cold front with significant cold advection in its wake.

Figure 1 depicts the differences in 2 m temperature (a), 2 m dewpoint temperature (b), 10 m u-wind (c), and 10 m v-wind (d) between the 3-hour forecast from WRF model initialized with ADAS (WRF-ADAS) and the ADAS analysis, valid at 1500 UTC 10 December 2009. The forecast differences between the cold start WRF model run (WRF-noADAS) and the ADAS analysis for the same time is shown in Figure 2.

At 1500 UTC the cold front extended southwest to northeast across the central Florida peninsula. At this time, WRF-ADAS slightly over-forecast the temperature (1-2 K) over the peninsula ahead of and behind the cold front (Figure 1a), but under-forecast it along the front. WRF-noADAS also over-forecast temperatures ahead of, along, and behind the cold front with a slightly higher bias of 3-5 K (Figure 2a). It is interesting to note that WRF-ADAS had a stronger cold bias than WRF-noADAS over the water surrounding the Florida peninsula. This may be due to the lack of observations over the open ocean and could most likely be circumvented by using high-resolution sea surface temperature data to initialize the model.

The same problem existed for the dewpoint temperature as evidenced in Figure 1b. Differences in both 2 m dewpoint temperature and 10 m u-wind between WRF-ADAS and the ADAS analysis (Figure 1b, c) were similar to those between WRF-noADAS and the ADAS analysis (Figure 2b, c), indicating that both model runs made similar forecasts for the 3-hour dewpoint temperature and u-wind. The v-wind (Figure 1d and Figure 2d) was also similarly forecast throughout the domain, except for along the front where WRF-noADAS had a strong northerly wind bias.

Figure 3 shows the differences in 2 m temperature (a), 2 m dewpoint temperature (b), 10 m u-wind (c), and 10 m v-wind (d) between the 9-hour forecast from WRF-ADAS and the ADAS analysis, valid at 2100 UTC 10 December 2009. The forecast differences between WRF-noADAS and the ADAS analysis for the same time is shown in Figure 4.

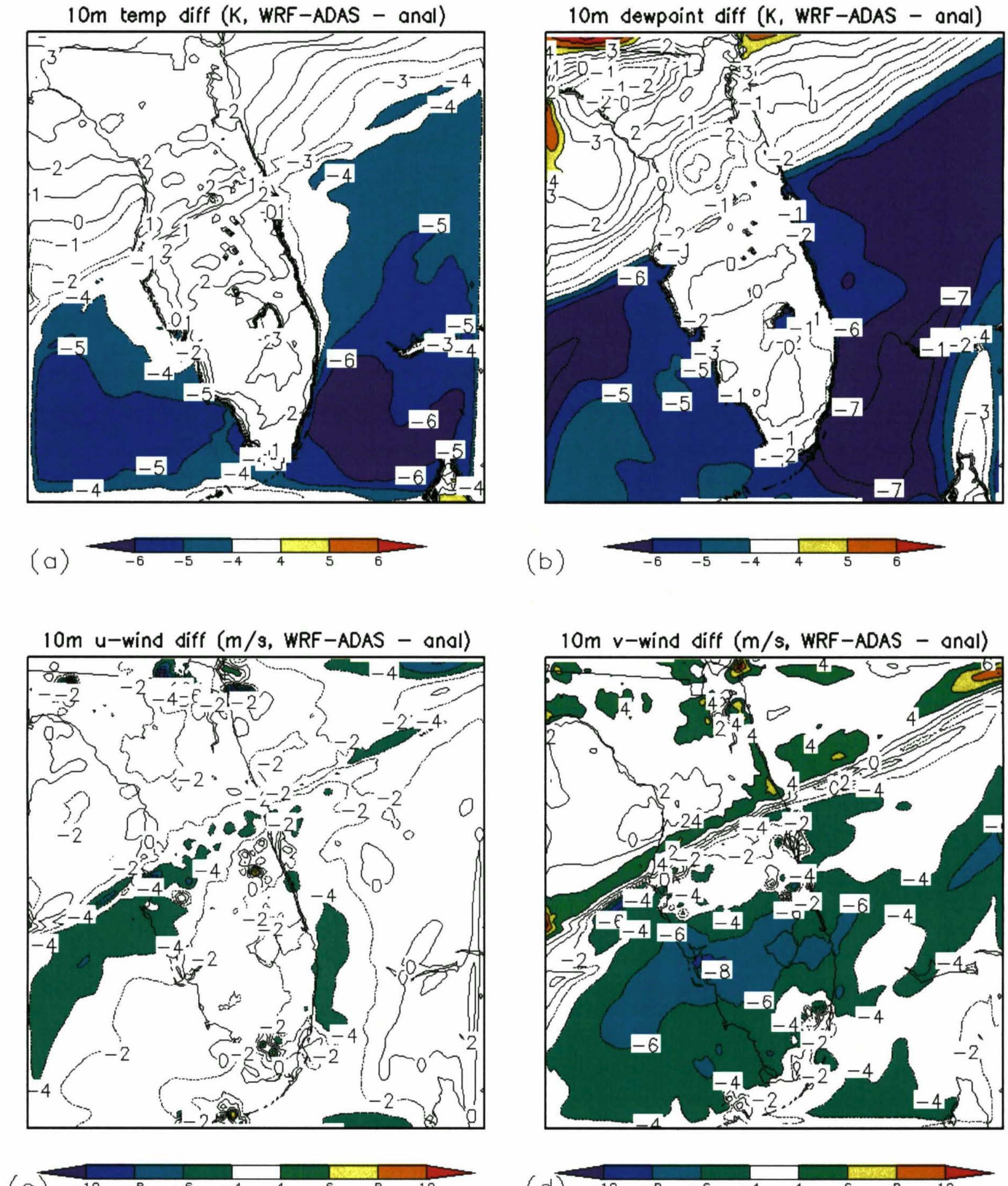

Figure 1. Differences in (a) 2m temperature, (b) 2m dewpoint temperature, (c) 10m u-wind, and (d) 10m v-wind between the 3-hour WRF-ADAS and the ADAS analysis, valid at 1500 UTC 10 December 2009.

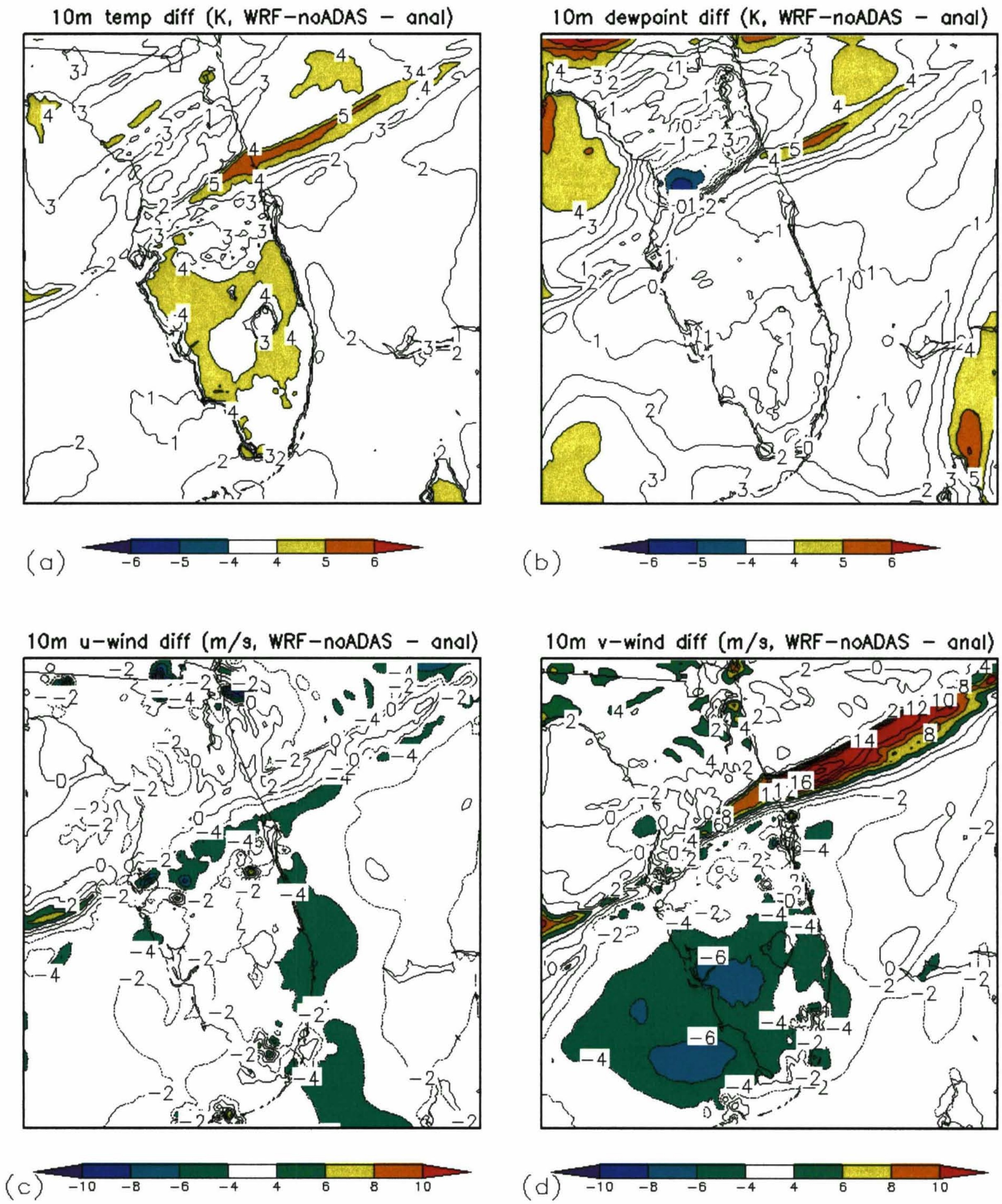

Figure 2. Differences in (a) 2m temperature, (b) 2m dewpoint temperature, (c) 10m u-wind, and (d) 10m v-wind between the 3-hour WRF-noADAS and the ADAS analysis, valid at 1500 UTC 10 December 2009.

By hour 9, both model runs were forecasting similar 2 m temperatures (Figure 3a and Figure 4a). WRF-noADAS had a slightly broader warm bias behind the front than did WRF-ADAS. The cold bias over the ocean in WRF-ADAS was still pervasive. The forecasts for 2 m dewpoint temperature for both WRF-ADAS (Figure 3b) and WRF-noADAS (Figure 4b) were similar over the peninsula. Differences in 10 m u- and v-wind between WRF-ADAS and the ADAS analysis (Figure 3c, d) were similar to those between WRF-noADAS and the ADAS analysis (Figure 4c, d), indicating that both model runs forecast similar 9-hour u- and v-wind. However, both WRF-ADAS and WRF-noADAS forecast a northerly component that was too strong along the front.

Figure 5 depicts the composite reflectivity from the ADAS analysis valid on 10 December 2009 at (a) 1500 UTC and (b) 2100 UTC, from WRF-ADAS at (c) 1500 UTC (3-hour forecast) and (d) 2100 UTC (9-hour forecast), and from WRF-noADAS at (e) 1500 UTC (3-hour forecast) and (f) 2100 UTC (9-hour forecast). The composite reflectivity is similar between WRF-ADAS and WRF-noADAS since, in general, the model handles synoptic scale features well. However, WRF-ADAS slightly outperforms WRF-noADAS at the 3-hour forecast by capturing the line of rain associated with progression of the frontal boundary. By the 9-hour forecast, differences are very slight.

6. CONCLUSIONS

This paper describes the AMU work on configuring ADAS for the operational needs of NWS MLB and SMG. The goal for running ADAS is to generate products that enhance issued short-range weather forecasts. Preliminary results from the cold season case study indicate using ADAS to initialize the WRF model can help forecasters develop a more comprehensive understanding of pertinent weather features versus a cold start model run. Initializing with ADAS particularly helps with the short-range forecasts (<6 hours). In this specific case study, using the short-range forecast from the WRF model initialized with ADAS would clearly have helped with the challenging temperature forecast. Using this type of scheme helps to enhance synoptic and mesoscale features in the initial conditions of a model run and helps to better forecast these features as well.

7. REFERENCES

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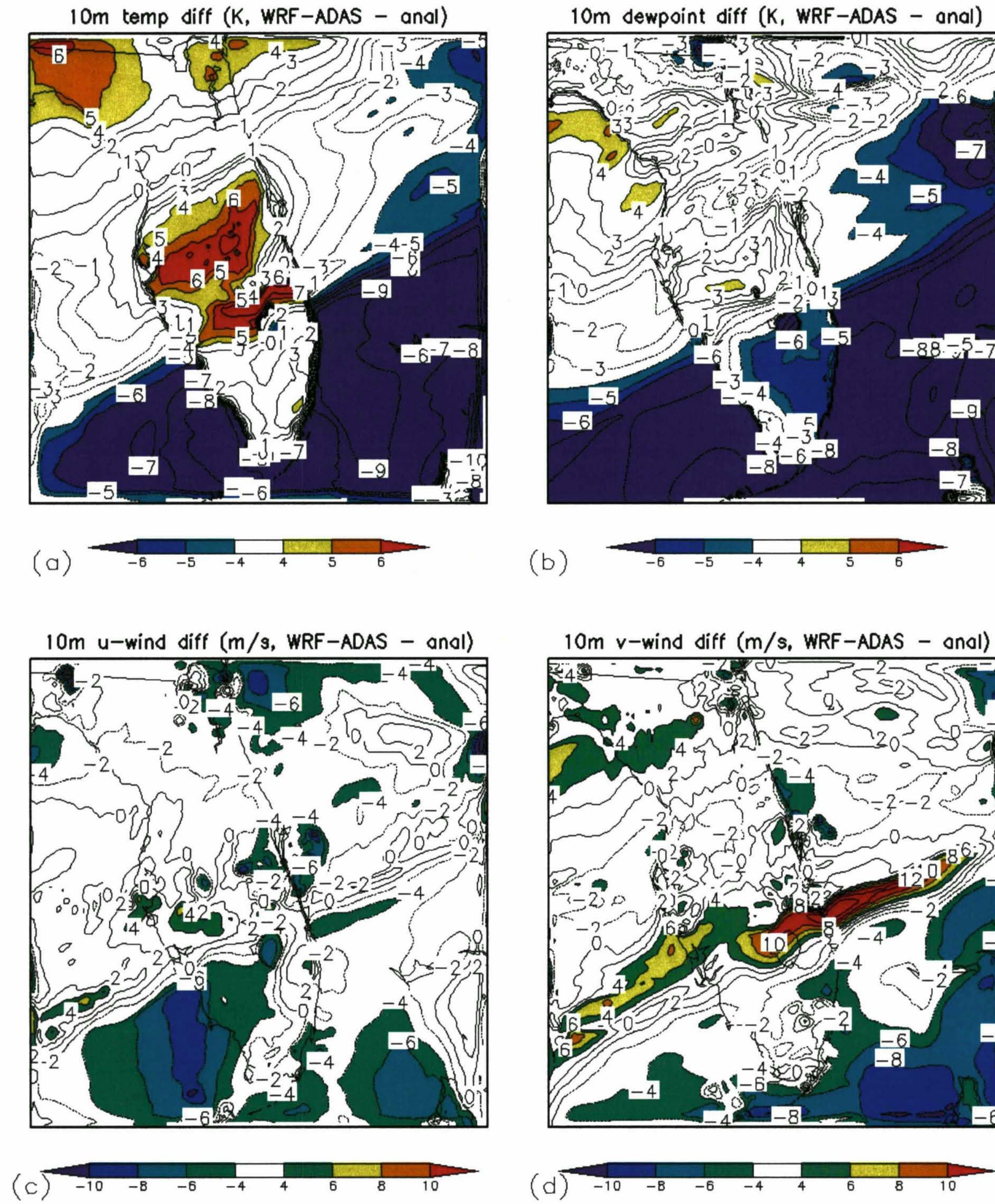

Figure 3. Differences in (a) 2m temperature, (b) 2m dewpoint temperature, (c) 10m u-wind, and (d) 10m v-wind between the 9-hour WRF-ADAS and the ADAS analysis, valid at 2100 UTC 10 December 2009.

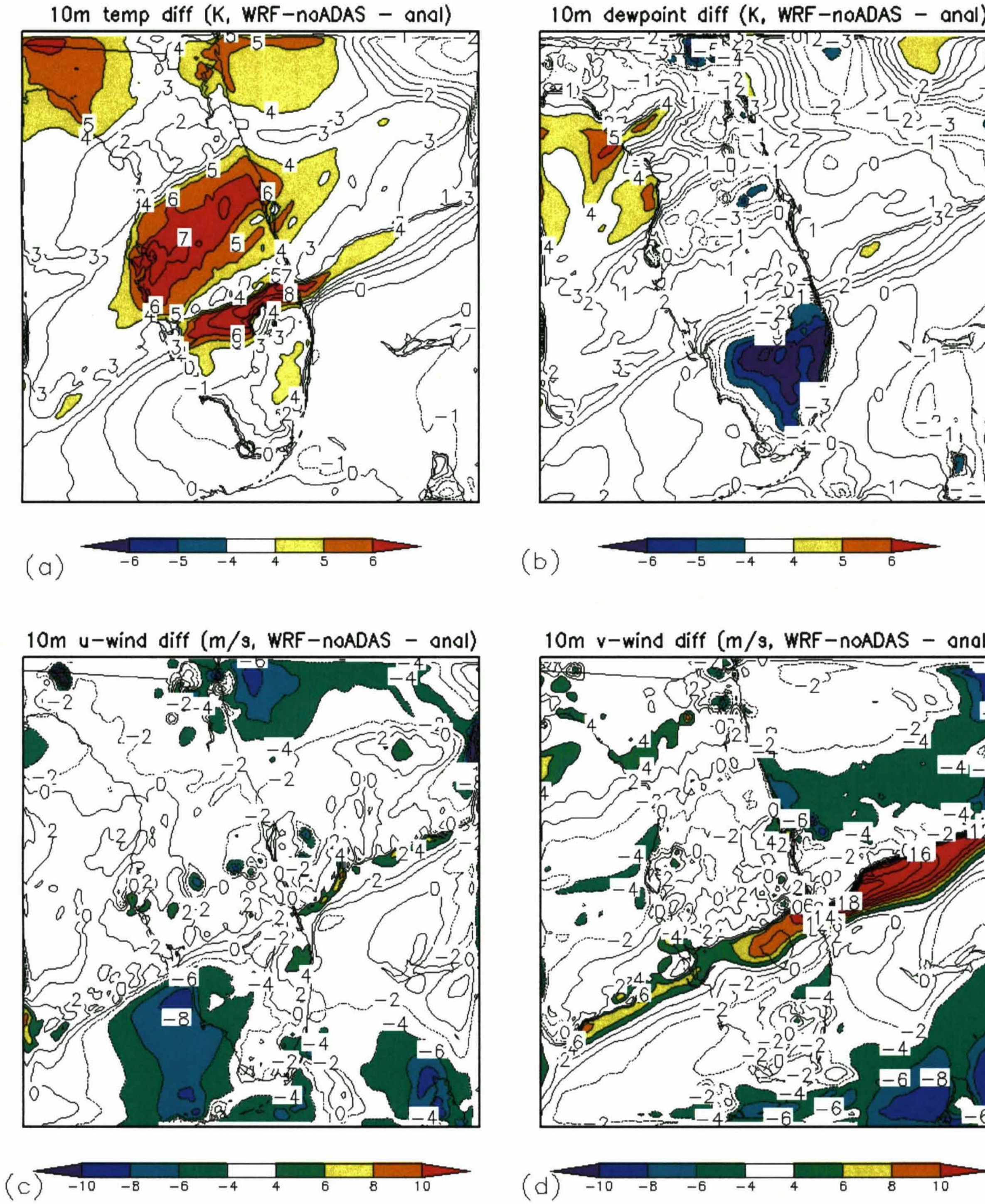

Figure 4. Differences in (a) 2m temperature, (b) 2m dewpoint temperature, (c) 10m u-wind, and (d) 10m v-wind between the 9-hour WRF-noADAS and the ADAS analysis, valid at 2100 UTC 10 December 2009.

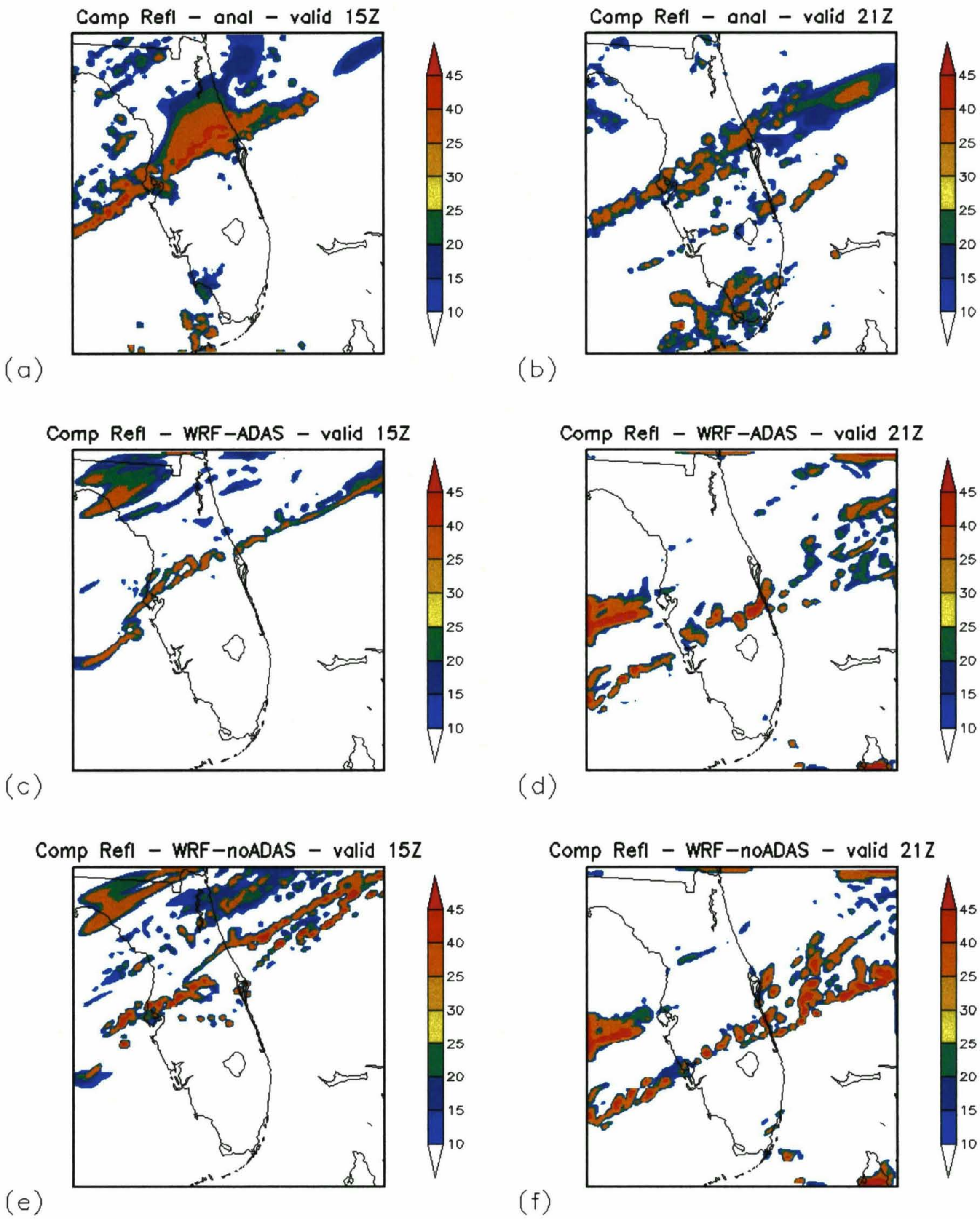

Figure 5. Composite reflectivity from the ADAS analysis valid at (a) 1500 UTC and (b) 2100 UTC, from the WRF-ADAS (c) 3-hour forecast valid at 1500 UTC and (d) 9-hour forecast valid at 2100 UTC, and from the WRF-noADAS (e) 3-hour forecast valid at 1500 UTC and (f) 9-hour forecast valid at 2100 UTC.