1.2 THE NCEP STAGE II/IV HOURLY PRECIPITATION ANALYSES: DEVELOPMENT AND APPLICATIONS

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1. INTRODUCTION

Two types of multi-sensor, real-time, 4-km, hourly/6-hourly national precipitation analyses are produced at NCEP and archived at NCAR as part of the GEWEX/GAPP effort: the more timely NCEP Stage II, produced directly from the real-time gauge and WSR-88D radar data received at NCEP, and the NCEP Stage IV, which is a mosaic of regional multi-sensor analysis produced by NWS River Forecast Centers (RFCs) and benefits from the RFCs' manual quality control step (see Fig. 1 for a side-by-side snapshot of Stage II/IV analyses). This paper gives an overview of the two analyses and their applications at NCEP. Further information about the analyses can be found at
http://www.emc.ncep.noaa.gov/mmb/ylin/pcpanl

2. THE STAGE II ANALYSIS

In 1995-1996, NCEP adapted the optimal rainfall algorithm developed by OHD (Seo, 1998) on a national 4-km grid (Baldwin and Mitchell, 1996) and produced a first national (ConUS), real-time, high-resolution, hourly, multi-sensor precipitation analysis from hourly radar precipitation estimates and hourly rain gauge data.

Each hour's analysis is first run at 35 minutes past the top of the hour (the "early" version of the analysis), then re-run 6 hours and 18 hours later (the "mid" and "late" versions). The "early" version uses the hourly precipitation reports from the ~1,450 ASOS sites obtained from the near-real time METAR file. The "mid" and "late" versions use the ~5,500 HADS automated gauge reports transmitted via the GOES Data Collection Platform (DCP). Currently most HADS

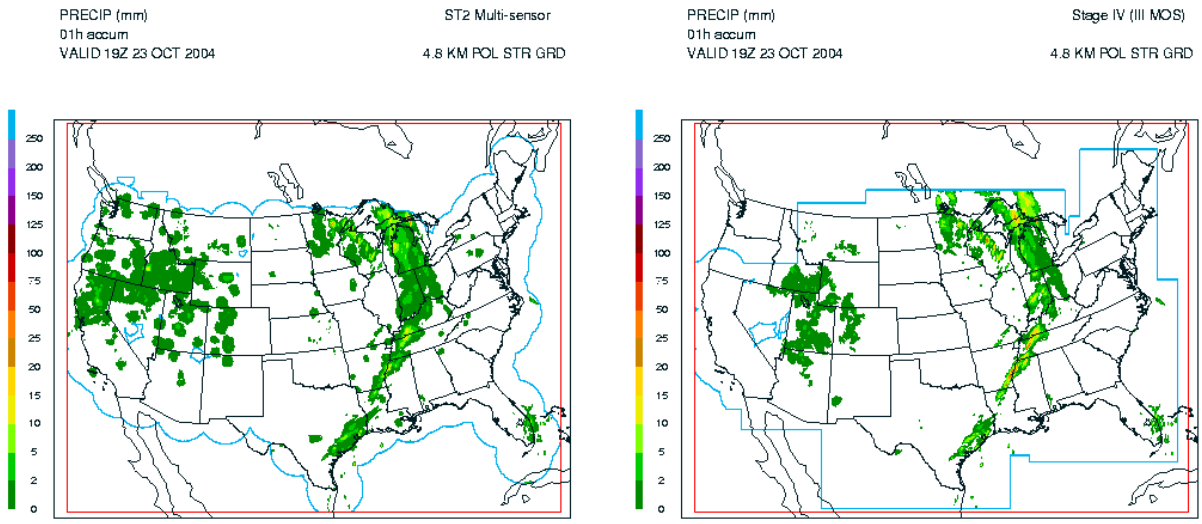

Fig. 1 Snapshot of a one-hour Stage II (left) and Stage IV (right) analysis.

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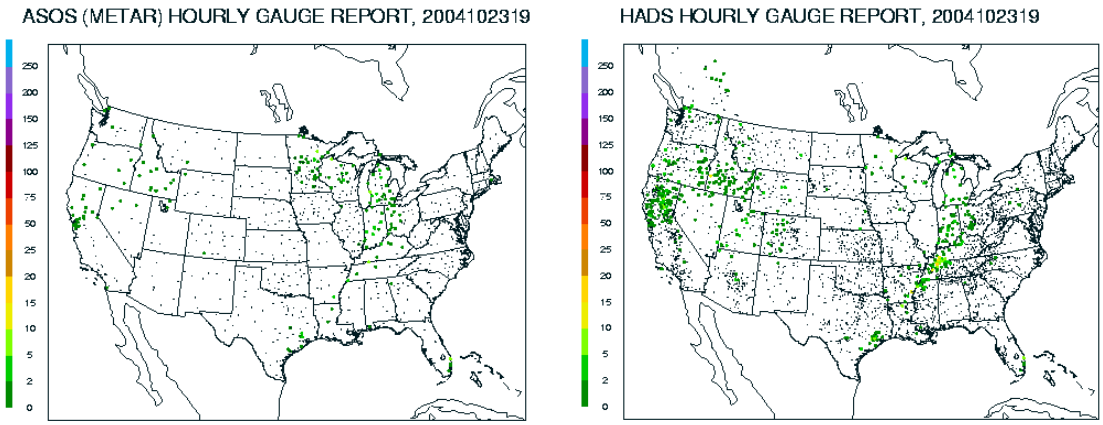

Fig. 2. Hourly ASOS (METAR) and HADS gauge reports valid at 2004102319. Black dots are reports of zero precipitation.

stations only transmit their data every 4 hours, hence the more timely METAR data are used to produce a "early" version of the analysis to meet the requirements of model precipitation assimilations. A snapshot of hourly ASOS and HADS gauge sites are shown in Fig. 2.

The radar data are the real-time Digital Precipitation Arrays (DPAs) produced at the approximately 140 ConUS WSR-88D radar sites (Fulton *et al.,* 1998). The DPAs contain running 1-hour precipitation totals generated from every radar volume scan. For our hourly analysis, for each radar, we choose the DPA from the volume scan that is closest to the top of the hour and falls into the +/-10 minute window centered at the top of the hour.

6-hourly and 24-hourly (12Z-12Z) totals are computed from the Stage II hourly analysis.

3. THE STAGE IV ANALYSIS

In late 2001 NCEP began to routinely generate another national multi-sensor analysis, the "NCEP Stage IV", mosaicked from the regional multi-sensor 1h and 6h analyses produced by the 12 ConUS RFCs.

The regional analyses done at the RFCs use more advanced versions of the multi-sensor analysis algorithm (*e.g.* Fulton and Kondragunta, 2002) and benefit from some manual quality control (QC) steps at the RFCs. Each RFC typically generate each hourly/6-hourly analysis twice, the first in the automated mode, done soon after the end of the accumulation time period, with no manual QC. The analysis is re-run several hours later in manual mode, where manual QC is performed by a human analyst.

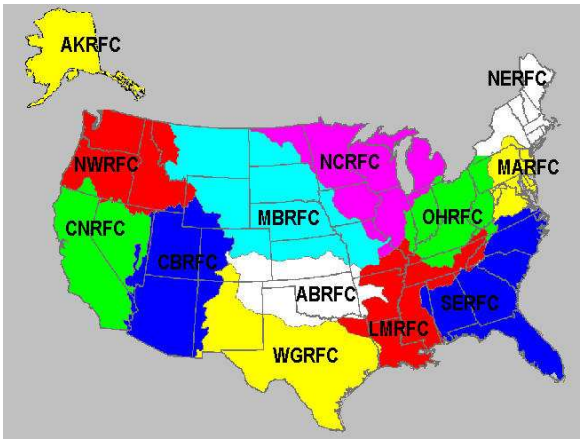

Fig. 3. RFC domains. Image from http://www.srh.noaa.gov/lub/wx/nws_HSAs.htm

At NCEP, the mosaicking for each hour/6-hour period is done via the following steps:

1) Gather all regional analyses available for that accumulation period; map the regional grid values to the national HRAP grid
2) If a point on the national HRAP grid falls into one of the RFC's domain (see Fig. 3), then the value from that RFC's analysis is used for this point
3) If a point on the national HRAP grid is not in any of the RFC's domain, but is covered by one or more RFC's analysis grid(s) (an

RFC's analysis grid is a regional polar stereographic HRAP grid that encompasses the RFC's domain), then the average value of all regional analyses covering this point is used as the mosaic value.

Due to resource/bandwidth limitations, each RFC sends NCEP around 4-6 'bundles' of analyses each day. A 'bundle' might contain several manually QC'd analyses for earlier hours and several automated (no QC) analyses for more recent hours. Receipt time for the hourly regional analysis ranges (roughly) from within an hour to 12 hours after. The four 6-hourly analyses covering the previous 12Z-12Z are generally received by 15Z (for the automated runs) and 21Z (the manually QC'd runs). A one-day snapshot of dataflow from MBRFC is shown in Fig. 4.

The NCEP Stage IV mosaic is performed at 35 minutes after the top of each hour. At that time, the mosaic job checks for any incoming regional analyses received in the past hour. If new data are received from at least one RFC, the job performs (or re-makes) a Stage IV mosaic for the hour/6-hour period(s) the new data cover. The timeliness of the Stage IV analysis depends on the data receipt time from the RFCs. Because different RFCs send their regional analysis bundles at different times, each hour/6-hour's mosaic might be updated a number of times. An Stage IV analysis might first become available an hour or two after the end of the accumulation time, but it might contain contribution from only one or two RFC(s), and the analysis will gradually get "filled in" in later hours by contributions from other RFCs. Generally speaking, hourly mosaics will be "finalized" 12-18 hours later, and 6-hourly mosaics covering a 24h period (12Z-12Z) will be "finalized" by 22Z. Summing of 6-hourly analyses into a 24h (12Z-12Z) analysis is done at 15:35Z, 21:25Z and 23:35Z.

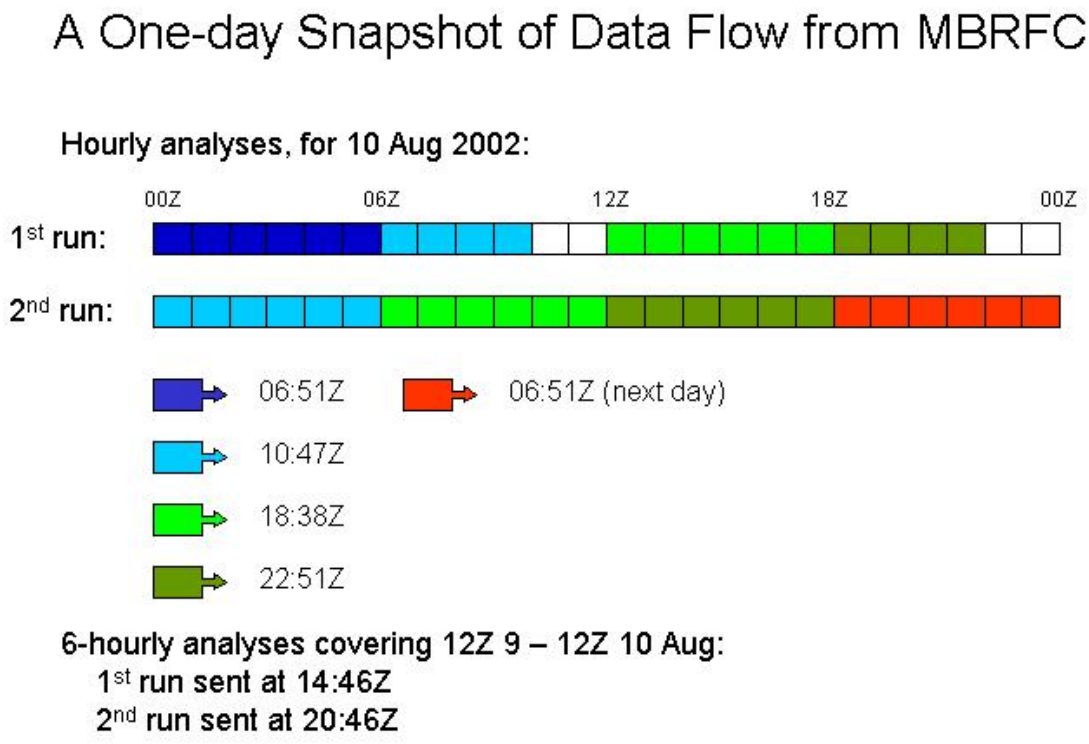

Fig 4. Example of data receipt time from Missouri Basin RFC.

4. ON-LINE DATA ACCESS AND PERMENANT ARCHIVE

Current Stage II/Stage IV analysis is available from NCEP's public ftp server at *ftp://ftpprd.ncep.noaa.gov/pub/data/nccf/com/hourly/prod/*nam_pcpn_anal.$yyyymmdd

The analyses are archived at NCAR CODIAC. Stage II data has been archived since May 1996. Stage IV has been archived since Jan 2002. Further details about the archive can be found in the NCEP Stage II/IV documentation.

5. APPLICATIONS AT NCEP

On Jul 2001, precipitation assimilation was implemented for Eta/EDAS (Lin *et al.*, 2001) with Stage II analysis as the precipitation input, which has improved the model's water cycle components, especially the model soil moisture, and made a small positive impact on the model's precipitation forecasts. In Jul 2003, the Stage IV analysis became the primary input for the Eta/EDAS precipitation assimilation, with the more timely (but less quality-controlled) Stage II serving as a supplement for when/where the Stage IV analysis is unavailable at the time of data ingest.

The Stage II/IV products are also used in deriving precipitation forcing for NCEP's North American Land Data Assimilation System (NLDAS; Mitchell et al., 2004). In NLDAS, the hourly Stage II/IV fields are summed to a daily field and then the hourly and daily fields are used to derive hourly temporal weights, which are used to disaggregate a daily gauge-only analysis of precipitation into hourly precipitation fields.

The Stage II has been used as verifying analysis for 3-hourly precipitation verification since Apr 1999 and has also been used in the verification of the Extended WRF Retrospective Tests.

6. PLANNED DEVELOPMENTS

A number of upgrades are planned for the Stage II analysis in 2005:

1) Upgrade the analysis algorithm to the latest Multi-sensor Precipitation Estimator algorithm
2) Implement automated gauge quality control: the hourly gauges are often subject to random and/or systematic errors. Currently we have a gauge reject list that is updated manually to eliminate gauges that have shown more egregious errors. FSL has developed an automated gauge QC package that monitors hourly gauge reports and flags down problematic gauges (Collander and Tollerud, personal communication).
3) Produce the Stage II/Stage IV analysis on the high-resolution 5km National Digital Forecast Database (NDFD) grid, and advance the "early" Stage II analysis to about 25 minutes after the top of the hour, in support of the National Weather Service's (NWS) effort to disseminate forecast products and verifying forecasts on NDFD grid.

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