# 3.3 USING HOURLY AND DAILY PRECIPITATION ANALYSES TO IMPROVE MODEL WATER BUDGET

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## 1. INTRODUCTION

Hourly precipitation analyses have been successfully assimilated into the Eta model since Jul 2001. They have made a significant improvement to the model's soil moisture field and a modest improvement on precipitation forecasts. However, the hourly analyses (NCEP Stage IV, supplemented by the more timely NCEP Stage II) tend to have a dry bias, and when they are assimilated directly into the model, over time the cumulative effect of small precipitation deficits can lead to noticeable dry bias in the model soil. We have developed a method to correct for this bias by keeping a long-term precipitation budget history array and using the array to modify the hourly input for precipitation assimilation.

## 2. PRECIPITATION ASSIMILATION IN ETA/EDAS

The essence of precipitation assimilation in the Eta Data Assimilation System (EDAS) is to make model fields more consistent with observed precipitation during the 12-hour pre-forecast data assimilation period. To that end, at each time step during EDAS, for each grid point where precipitation observations are available, we compare the model precipitation against the observed amounts and make adjustments to the model's latent heating, moisture, cloud water and hydrometeor fields accordingly. In Jul 2001, precipitation assimilation using the NCEP Stage II analysis (a national, 4-km, hourly analysis from hourly radar and rain gauge data) was operationally implemented for the Eta model. In Jul 2003, the Stage IV analysis (regional hourly multi-sensor analysis from the 12 RFCs mosaicked at NCEP; with some manual QC done at the RFCs) became the primary input for the Eta/EDAS precipitation assimilation, with the more timely Stage II serving as a supplement for when/where the Stage IV analysis is unavailable at the time of data ingest.

We have found that precipitation assimilation significantly improves the model's precipitation field during EDAS, and as a result has a positive impact on the soil moisture field. Precipitation assimilation also often has a significant positive impact on the first 6 hours' of the model's precipitation forecast, and a small positive impact on longer-term forecasts (Fig. 1).

## 3. THE DRY BIAS IN HOURLY ANALYSES

Precipitation assimilation enables model soil moisture field to be much more closely related to actual rainfall (since there are no real-time nationwide network of root-zone soil moisture observations available for assimilation, the model soil moisture is driven by model rainfall during data assimilation). There was one problem, however: the hourly radar-and-gauge based Stage II and Stage IV analyses typically contain some systematic dry bias. When used as primary driver for soil moisture, small, systematic bias can build up over time into a large soil moisture bias. An example is shown in Fig. 2, where the monthly total rainfall into the soil is compared to the monthly rainfall computed from daily gauge observations.

## 4. CORRECTION OF THE DRY BIAS

We seek to correct for the systematic bias by comparing the 24h sum (12Z-12Z) of the hourly input for the EDAS against a daily gauge analysis, and use the cumulative differences to make modest adjustment to the hourly precipitation input.

The daily gauges (12Z-12Z) are usually more accurate than either radar precipitation estimates or hourly gauge reports. The analysis we use here is based on 7,000-8,000 gauges, quality-controled and analyzed to a 1/8 grid by NCEP/CPC.

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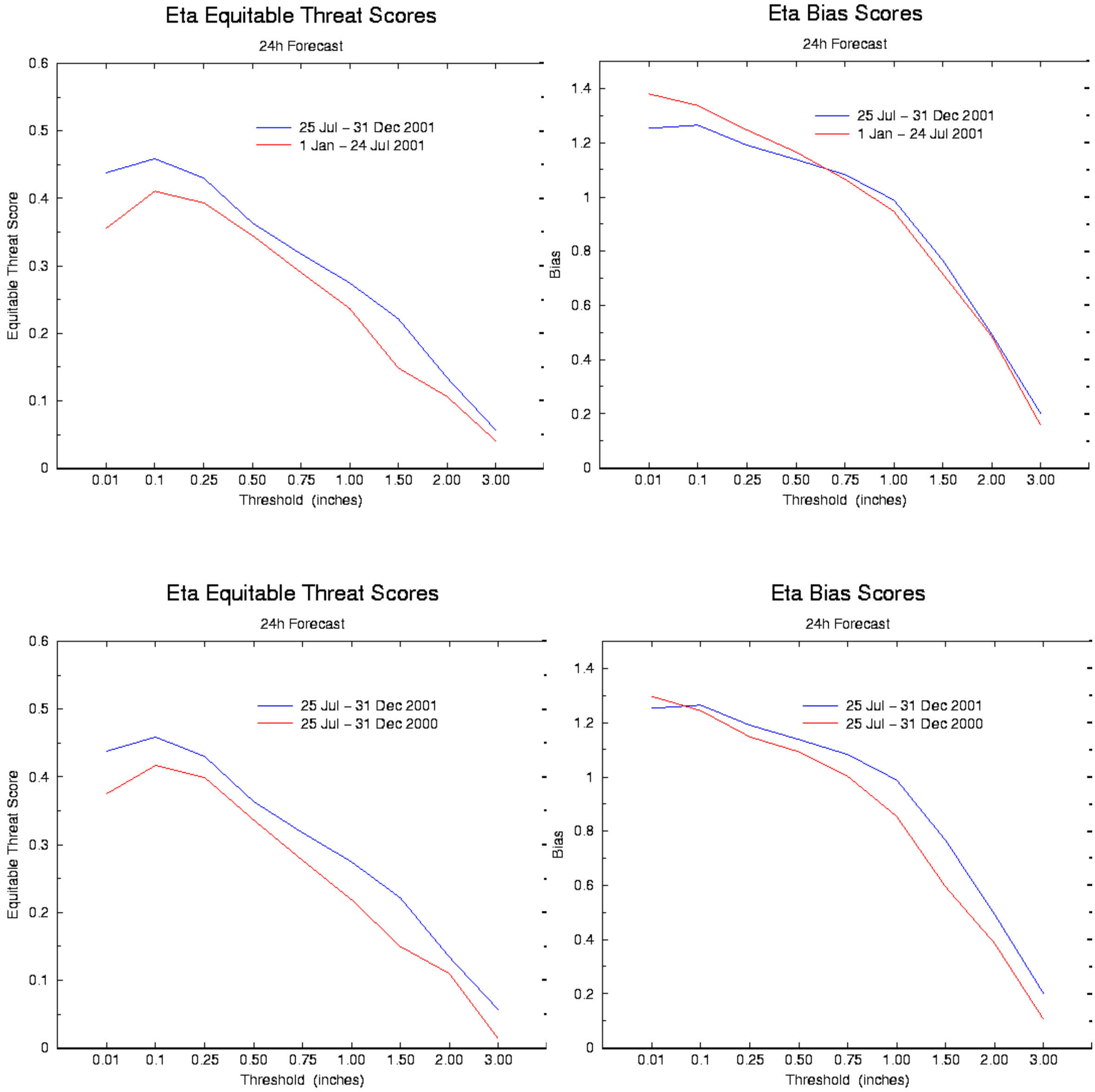


Fig. 1. 24h Eta precipitation forecast threat and bias scores. Top panels: scores for 2001, before and after the 24 Jul implementation. Bottom panels: scores for 25 Jul-31 Dec, 2000 vs. 2001. Note there were other contributing factors to the score improvement: the 24 Jul implementation also included upgrades to land surface physics and 3DVAR analysis; another implementation on 27 Nov 2001, which included a new cloud microphysics package, increase of resolution to 12km/60levels, and assimilation of NOAA-16 radiances in 3DVAR.

The process of the adjustment is as follows:

1) Each day at 06Z, update the precipitation "budget history" file:
   a) Compute a 24h (the previous 12Z-12Z) 'snow map' from the EDAS hourly 'snow ratio' arrays (when the ratio is larger than or equal to 90%, the precipitation is likely to be snow; Fig 3. shows that this snow ratio is a good indicator of the actual presence of snow) showing where it has snowed during the 24-hour period. We do not assimilate the hourly precipitation analysis when it is snowing (bias from hourly precipitation data is too large during snow), so at a given

grid point, if it snowed during any of the 24 hours, we exclude this grid point from budget history calculations.

b) Compute the sum of the EDAS precipitation during the 24 hours (12Z-12Z). When precipitation assimilation is done, this sum is quite close to the 24h sum of hourly precipitation input for EDAS. We use EDAS precipitation instead of the input precipitation analysis, because the EDAS precipitation is what drives the model soil moisture.

c) Map the daily gauge analysis from the 1/8 deg grid to the Eta grid

d) Compute the difference between daily sum of EDAS precipitation (from b) and and daily gauge analysis multiplied by 1.1 (we add a 10% "inflation factor" to the daily gauge analysis because daily gauges also tend to have a 10% low-bias due to problems of under-catch, *i.e.* "slanted rainfall"). Add this difference to a long-term cumulative precipitation difference array. This will be referred to as the "budget history".

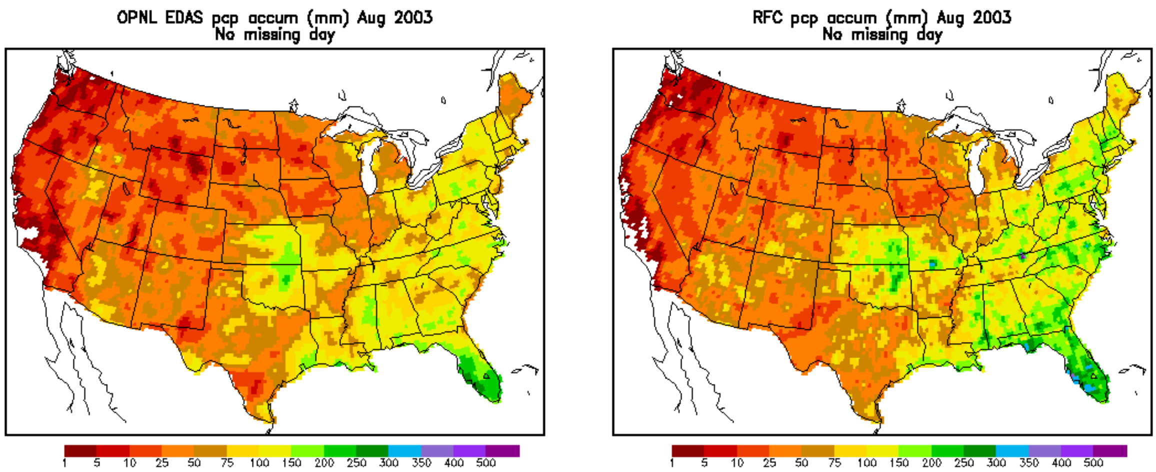


Fig. 2. Aug 2003 total rainfall. Left panel: rainfall in EDAS (*i.e.* fed into the model soil); right panel: rainfall from daily gauge observations.

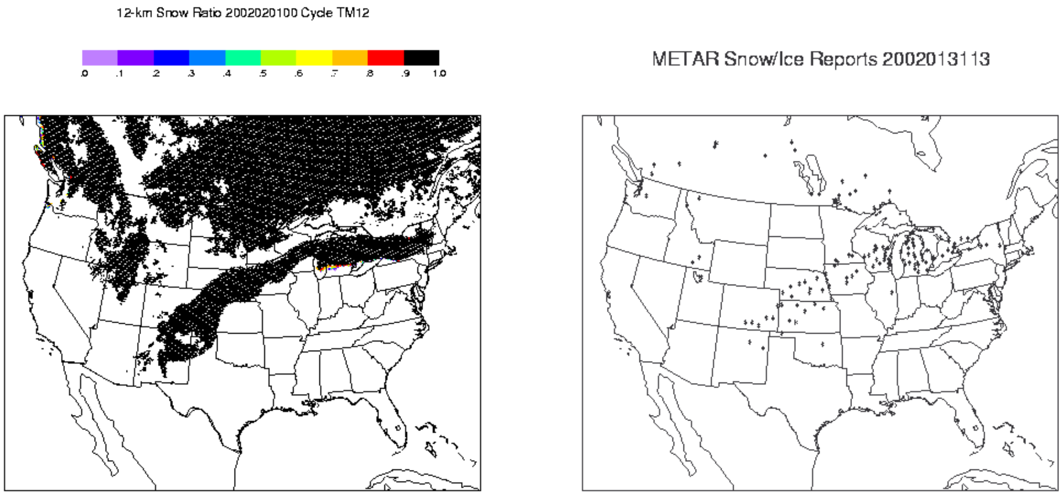


Fig. 3. Left panel: 12-km Eta/EDAS snow ratio (*i.e.* percentage of precipitation falling on the ground that is frozen), during the first hour of the 12-hour pre-forecast assimilation period for model cycle 2002020100 (*i.e.* valid at 2002013113). Right panel: ASOS snow/ice reports, from METAR file for the same hour.

2) Use the budget history file to modify the hourly precipitation input for EDAS. The modification is done on grid points with non-zero precipitation, with the aim (seldom realized) of zeroing out the imbalances in the budget history within the next 24 hours. To that end, for each non-zero grid point in an hourly precipitation analysis used as input to EDAS, we attempt to add/subtract 1/12 of the total deficit/surplus to it (we make a rough assumption that if it rained at a given location within a 24h period, the rain happened in 12 out of 24 hours), with the maximum addition/subtraction limited to 20% of the original analysis value. For example, if the "budget balance" at point (x,y) is -24mm (a deficit), and the 'current' hourly precipitation at (x,y) is 3mm/hr, the modified value would be 3.6mm/hr.

An example of the precipitation budget history is shown in Fig. 4.

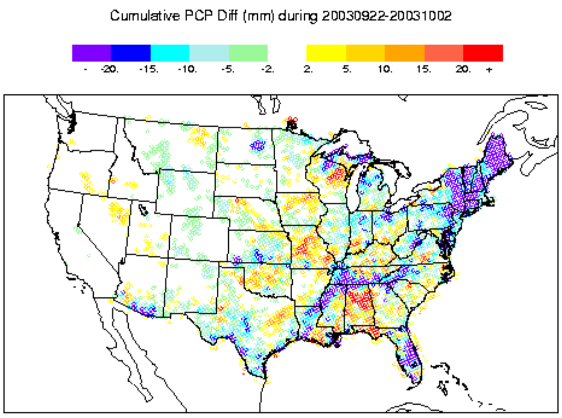


Fig. 4. Cumulative precipitation budget (EDAS precipitation – 1.1*daily gauge observations) during 20030922-20031002. From a 32-km Eta/EDAS parallel experiment.

## 5. RESULTS AND DISCUSSIONS

The budget-history adjustment approach reduced the assimilated precipitation dry bias significantly and improved EDAS precipitation accuracy, as shown in Fig. 5. As a result, soil moisture dry bias is also alleviated (Fig.6).

The approach was tested extensively, both as a stand-alone feature and along with other Eta upgrade components. On 16 Mar 2004 an Eta upgrade took place, implementing the precipitation budget adjustment, the assimilation of GOES cloud top radiances, and improved land surface physics.

The implementation of precipitation assimilation in 2001 greatly improved the water cycle components in the Eta model. The budget adjustment is an additional step that further fine-tuned the model's water budget balance. Though we are primarily concerned with dry bias in the hourly precipitation analyses, the adjustment approach will also work well if/when the hourly analyses are too wet. Like the precipitation assimilation itself, the adjustment procedure is computationally inexpensive.

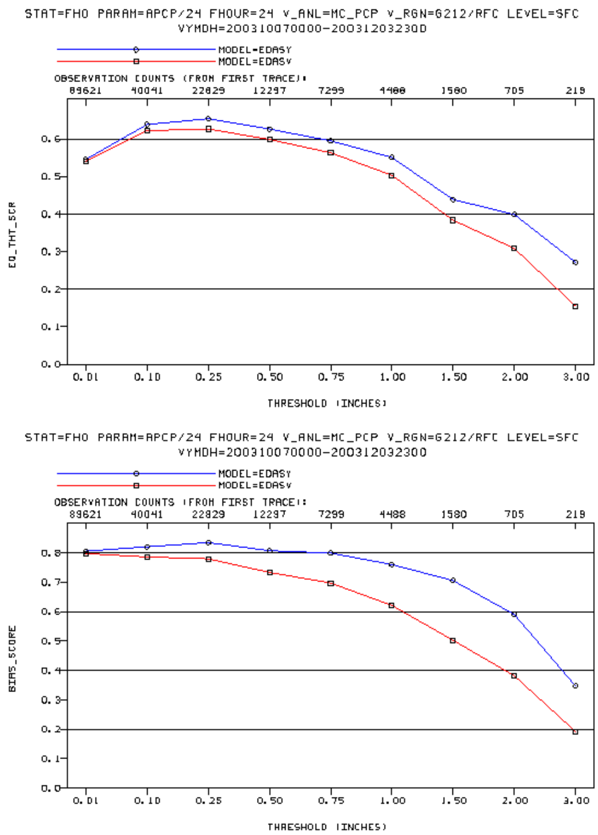


Fig. 5. Equitable threat (top) and bias (bottom) scores for EDAS precipitation during a 32-km Eta/EDAS parallel experiment, 20031007-20031203. The blue lines are scores for the run with the budget adjustment. The red lines are scores for the control run, without the budget adjustment.

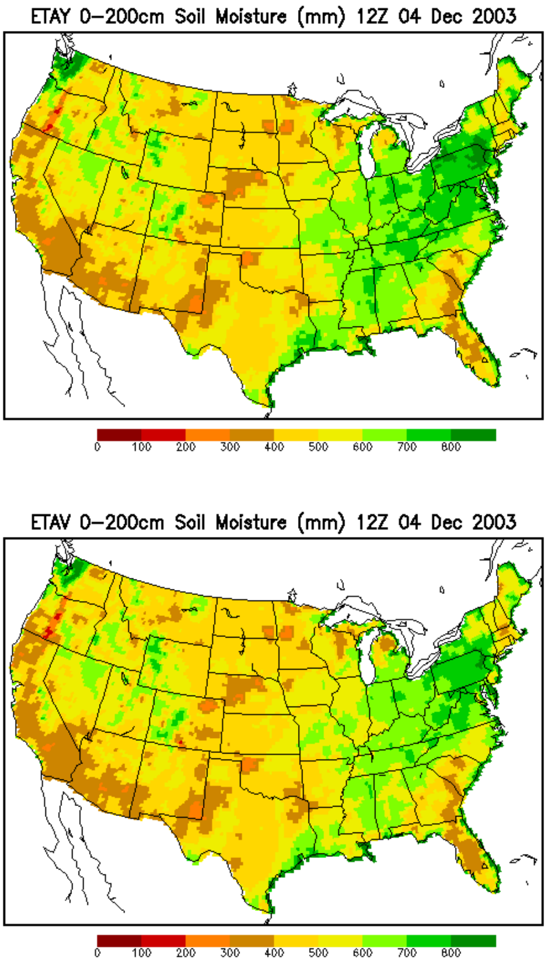


Fig. 6. 32km Eta parallel runs, top 2-m soil moisture fields. Top: after 2 months run with precipitation budget adjustment; bottom: control run, without the budget adjustment.

## REFERENCES


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