# 2.10 ANALYSIS OF WATER BALANCE SIMULATION OF LAND DATA ASSIMILATION SYSTEM

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## 1. INTRODUCTION

The multi-agency/university North American Land Data Assimilation System (N-LDAS) project is designed to provide enhanced soil and temperature initial conditions for numerical weather/climate prediction models by using real-time observed precipitation and solar insolation data. Currently four different land surface models (LSMs) are running in N-LDAS in both retrospective mode as well as in realtime. All LSMs are initiated at the same time with the same relative soil wetness.

This study examines the degree of correlation between the water balance simulations among different models and how this may vary with time. The results of this study should provide important insights into the similarities and differences of the four LSMs in N-LDAS. Further, this study should also shed light on the spin-up properties and possibility of using soil moisture states from one model to estimate initial soil moisture states from another model.

## 2. DEVELOPMENT OF THE DATA SETS

The LDAS project is primarily designed to provide enhanced initial land surface states such as soil moisture and soil temperature for coupled land/atmosphere models running at continental scale. This is done by running the LSM offline from the coupled model with forcing data comprised of real-time observed precipitation and solar insolation, together with analyzed fields of air temperature, surface pressure, humidity and wind speeds.

The state variables from the offline simulations can be used to initialize the coupled land/atmosphere models. Because LDAS uses realtime observations, biases inherent in recycled states in coupled models are avoided. Another benefit of LDAS is that the outputs from LDAS can be analyzed to gain valuable insights into climate variability at continental scale and into strengths and limitations of model physics.

Currently there are four LSMs running in LDAS: NOAH model from NCEP, MOSAIC model from NASA, VIC model from Princeton University and the Sacramento model (SAC) from the National Weather Service River Forecast System.

LDAS runs in two modes: realtime and the retrospective. In the realtime mode, realtime forcing data for the current day are used to drive the LSMs. Realtime runs were initiated on April 11, 1999. However, there are some data quality control issues associated with the realtime forcing data.

Retrospective LDAS runs focus on a three-year time period from October 1, 1996 to September 30, 1999. The retrospective data sets are more reliable than the realtime data because more data quality control measures were exercised. In this paper, the analysis was conducted on the model simulation results using the retrospective forcing data.

All LSMs were assigned the same relative soil wetness values at the end of September 30, 1996. Snapshots of the soil moisture fields from all 4 LSMs were obtained at the end of the first and fifteenth days. A total of 36 soil moisture snapshots were collected from each of the LSMs for the entire LDAS domain.

This paper presents preliminary analyses of these 36 soil moisture snapshots. Ideally, we would like to compare how different water state variables compare across the different models. This is difficult to do because there are important differences in how the moisture state variables are defined. But there is enough similarity in definition of the total water storage to permit a straight forward comparison.

## 3. TIME SERIES OF BASIN AVERAGE TOTAL WATER STORAGE

Because land surface models conserve water and energy, changes in any part of a model have effects on every other part of the model. Therefore, the total amount of water stored in a model at any given time depends on the details of the given model.

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Time series of areal average total water storage were computed for the forecast area of each of for each of the 12 NWS River Forecast Centers for each of the 4 LDAS LSMs for water years 1997-1999. The locations of the RFC forecast areas is shown in Figure 1. These areas were chosen for this analysis because each RFC has a different average climate regime.

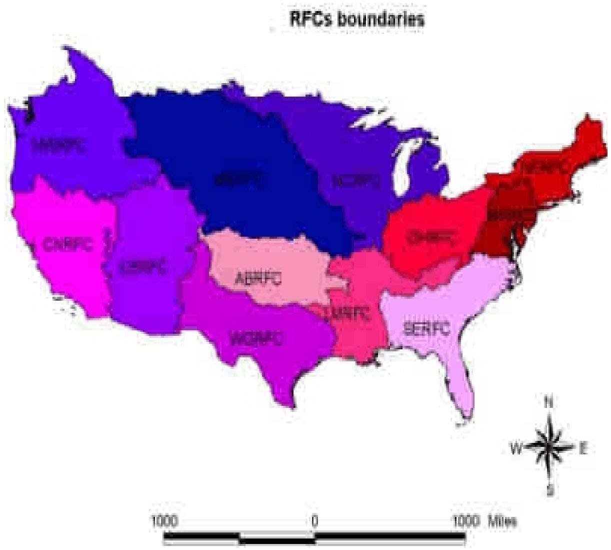


**Figure 1** - River Forecast Center Boundaries

The RFC labels in Figure 1 are defined in Table 1.

The resulting time series for each of the 4 models for each of the RFC's is shown in Figure 2. These are organized from dry to wet climate regime from upper left to lower right respectively. A climate index (P/PE) equal to the ratio of mean annual precipitation to mean annual potential evaporation was used to sort the RFCs in Figure 2. The mean annual precipitation for each RFC was computed from the mean annual PRISM estimate for the period 1961-1990. The mean annual potential evaporation estimate was taken from the NOAA evaporation atlas. The values of the P/PE climate index also are given in Table 1.

There are some apparent general patterns that occur in Figure 2 as climate changes. For example, the spin-up time for the model total water storage to get in equilibrium with the model climatology is longer for dry climates than for wet. Of course this also depends on how far away the initial conditions at the start of the simulations were assumed to be from where they needed to be to avoid spin-up problems.

Table 1 - RFC Label Definitions

| Label | RFC Name | P/PE |
|---|---|---|
| CBRFC | Colorado Basin RFC | 0.29 |
| CNRFC | California/Nevada RFC | 0.37 |
| WGRFC | West Gulf RFC | 0.37 |
| MBRFC | Missouri Basin RFC | 0.50 |
| ABRFC | Arkansas Basin RFC | 054 |
| NCRFC | North Central RFC | 0.82 |
| NWRFC | North West RFC | 0.96 |
| MARFC | Middle Atlantic RFC | 1.03 |
| SERFC | South East RFC | 1.04 |
| NERFC | North East RFC | 1.22 |
| LMRFC | Lower Mississippi RFC | 1.29 |
| OHRFC | Ohio RFC | 1.33 |

With the exception of CNRFC, RFC areas with P/Pe less than 0.6 have spin-up problems that may last as long as 2 years. CNRFC does not follow the pattern because CNRFC includes the Sierras and the Coastal Range. The spatial coefficient of variation, Cv, of P/Pe for the CNRFC is 1.13. This is much larger than Cv for any other RFC except NWRFC for which Cv is 1.

RFCs with P/PE greater than 0.60 have larger amplitudes of seasonal variation of total water storage. The seasonal variation of total water storage in the dry areas is not very strong.

The NOAH and Mosaic models have the most similar values of total water storage and this is consistent for all RFCs. The Sacramento and VIC models have similar total water storage variability in the wet areas but not in dry.

The Sacramento model does not seem to have any significant spin-up problems for any of the RFCs.

# Basin Average Total Water Storage for NWS River Forecast Centers

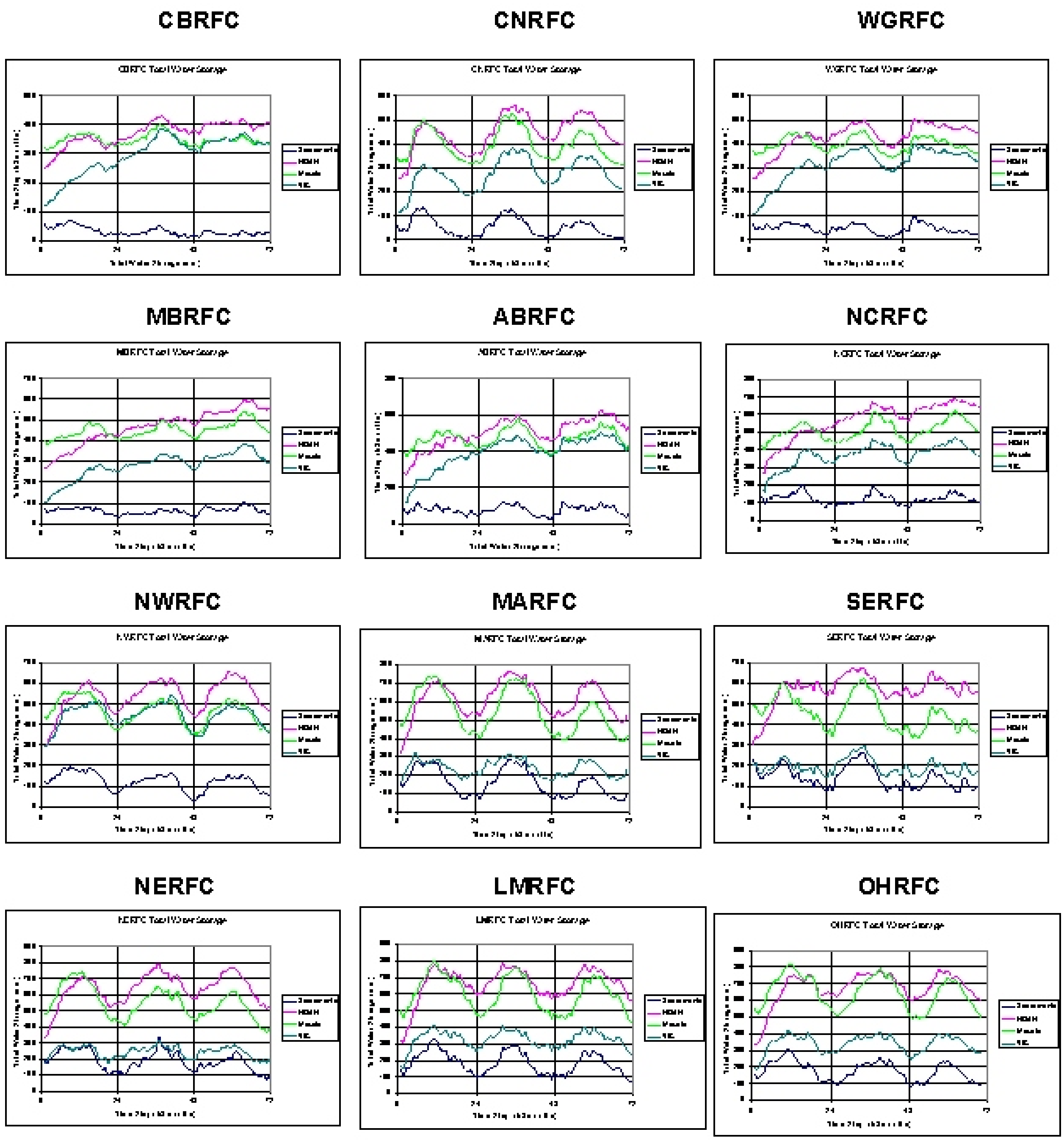


**Figure 2** - Time series of total water storage for 12 NWS RFC forecast areas

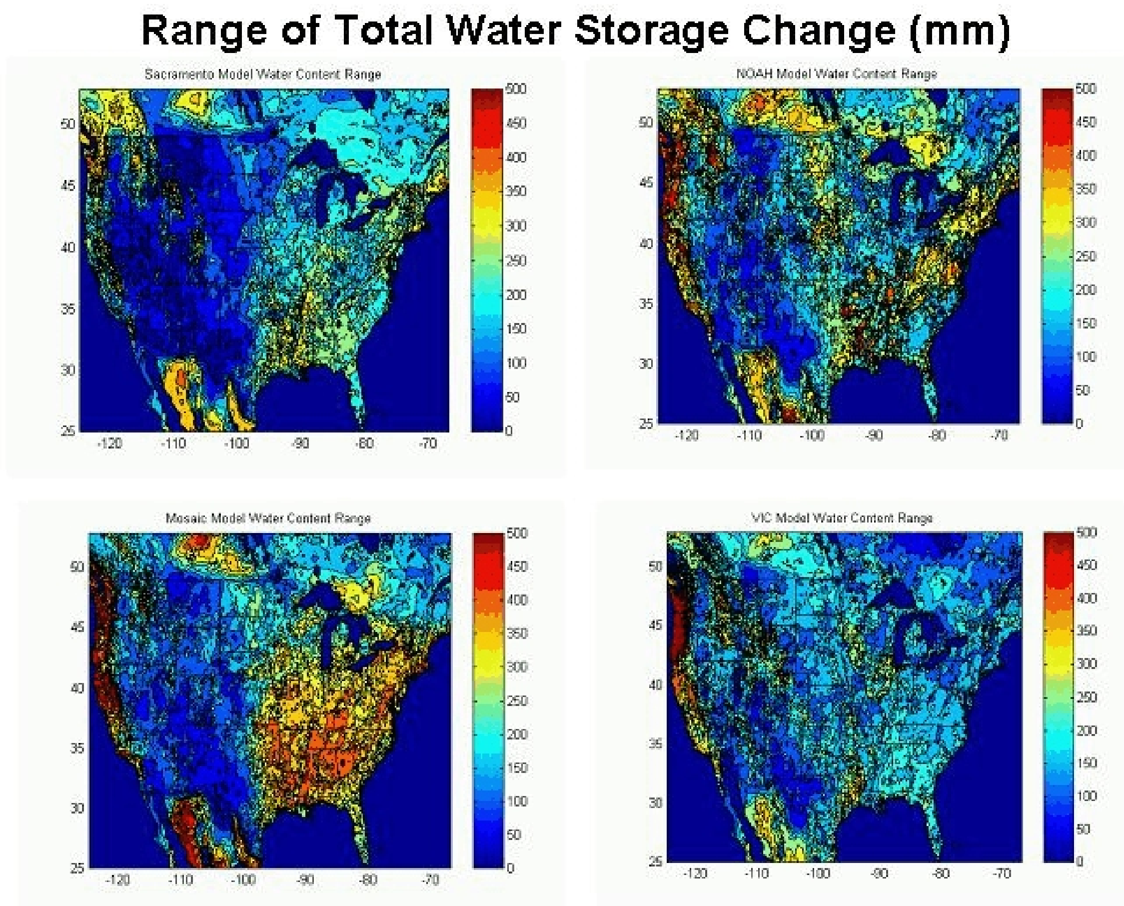


**Figure 3** - Maximum range of total water storage change in 4 LDAS Land Surface Models during water years 1998-1999

## 4. MAXIMUM RANGE OF TOTAL WATER STORAGE

It might be expected that changes in total water storage might be more comparable between models than the amount of total water storage since the rate of change of water storage appears in the continuity equation that governs the water balance. This is apparent in Figure 2 where curves for different models would be in closer agreement if they were simply shifted up or down.

Accordingly the maximum range of total water storage was computed for each LDAS grid point. To avoid spin-up effects only the last 2 years of the simulation were used to do this. The results appear in Figure 3. The Mosaic model has the greatest range in the humid southeast. This is consistent with the time series results shown in Figure 2. Again the patterns of Mosaic and NOAH are most similar for the entire LDAS domain. The Sacramento model shows the smallest range of total water storage change in the very dry regions.

It was clear from Figure 2 that total water storage depends on climate regime. Therefore, RFC average values of the range of total storage change are compared to the P/PE climate index in Figure 4. In very wet climates Mosaic has the greatest range, which cam be observed in Figure 3 as well. Mosaic and Sacramento exhibit the strongest relationship. There is only a weak relationship between VIC range of water storage and P/PE.

## 5. CONCLUSIONS

This preliminary study has found both strong similarities and differences between the models and with the P/PE climate index. The study will continue to quantify additional relationships.

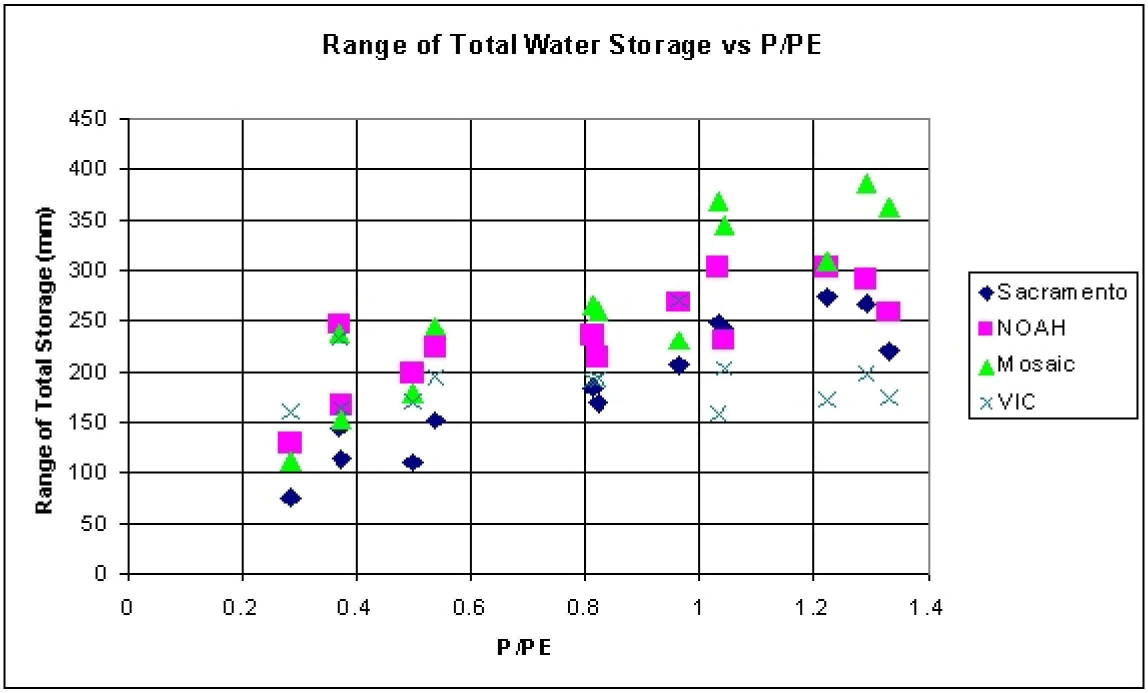


**Figure 5** - Range of total water storage vs P/PE

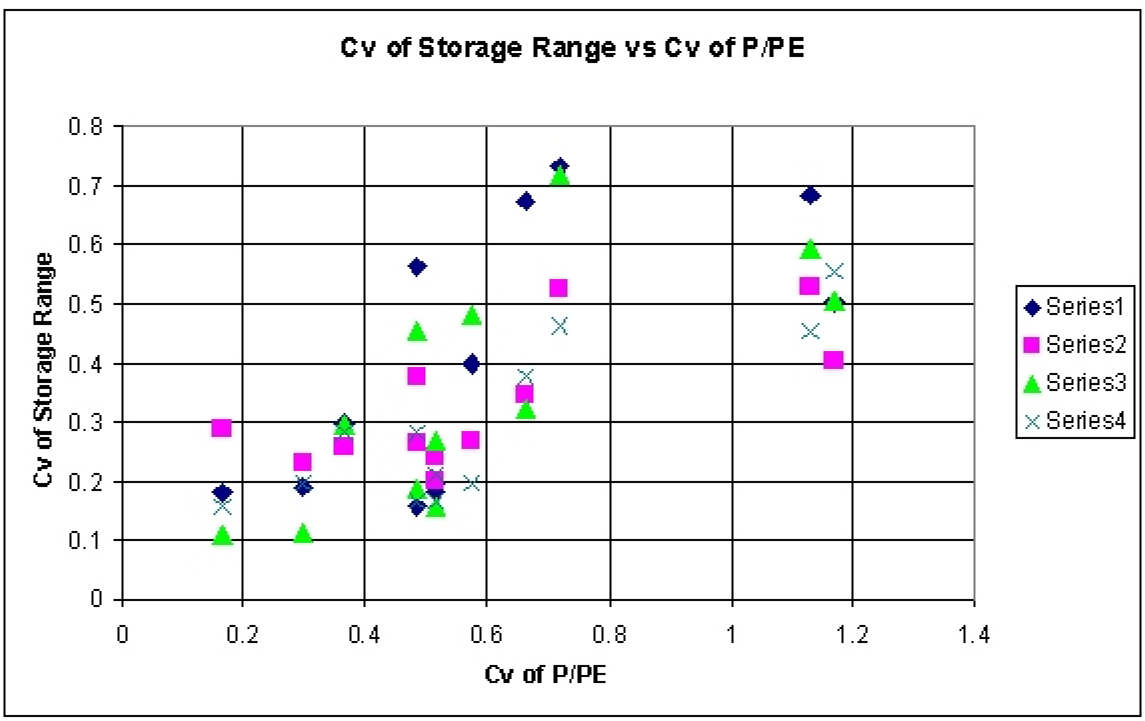


**Figure 6** - Cv of storage range vs Cv of P/PE climate index