P1.18 FIRST STEPS TOWARD AN OFF−LINE SURFACE (SOIL MOISTURE) ASSIMILATION SYSTEM AT THE METEOROLOGICAL SERVICE OF CANADA

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1. INTRODUCTION

In a continuous effort to improve the representation of surface processes in the Global Environmental Multiscale (GEM) model which is currently used operationally for both short (regional) and medium−range (global) weather forecasting at the Canadian Meteorological Centre (CMC), a new surface modelling system was implemented in September 2001 (see Bélair et al. 2003a and 2003b). In this new system, more sophisticated models are used to represent processes over continental, sea−ice, and glaciers surfaces. For the continental portion of the surface, an improved version of the Interactions between Surface, Biosphere, and Atmosphere (ISBA) surface scheme is included in this package.

To perform the very important task of properly initializing the soil moisture and surface temperature used by ISBA, a sequential assimilation technique based on optimal interpolation was also implemented with the new surface modelling system. In this assimilation system, model errors on screen−level air temperature and relative humidity (taken at 1800 UTC over the North American continent, i.e., at the time of greatest solar insolation) are used to calculate analysis increments on soil moisture and surface temperature .

The major improvement related to the implementation of this new system was described in Bélair et al. (2003a, 2003b). In summertime, the mean Bowen ratio is significantly larger than in the previous operational model. This lead to a much drier and warmer planetary boundary layer (PBL) that compared better with observations. Objective evaluation against radio−sonde data showed that the cold and humid biases that were present in the old system were practically eliminated by the implementation of the new system. The generally warmer and drier PBL, in turn, had an impact on precipitation: the increase of precipitation bias (with integration time) that was systematically found with the previous operational model was significantly reduced. In wintertime, the inclusion of ISBA, even though it included a substantially improved snow package, had less impact on the objective verification of temperature, humidity, and precipitation.

The results that will be presented at the conference are part of our effort to improve the representation of surface processes in GEM. In particular, we are now examining the advantages of using an off−line surface assimilation system to produce initial values of soil moisture and surface temperature for CMC's regional forecasting system. One of the main objectives of the present study is to compare the evolution of soil moisture produced by two off−line assimilation systems with that given by the sequential assimilation system described above. The impact of using radar observations for the precipitation forcing will also be examined.

2. EXPERIMENTAL SET−UP

An off−line version of the new surface modelling system that was recently implemented at CMC was developed and integrated over North America at a resolution of 10 km (600 x 600 points). In this off−line model, all the surface forcing (radiation, precipitation, and low−level air temperature, humidity, and wind speed) is provided from external sources. In the present study, we integrated the off−line system twice for 2002's warm season, i.e., from 1st May to 31 August 2002. For the first assimilation cycle (hereafter referred to as OFF1), all the surface forcings were obtained from the first 24 hours of integration of CMC's short−range regional operational forecast (covering most of North America at a resolution of approximately 24 km). Therefore, the forcing for this first off−line cycle is very similar to the forcing that was given to the in−line surface modelling system (referred to as IN). The differences for the evolution of the surface hydrology in OFF1 and IN should thus mostly come from the assimilation increments applied to surface temperature and soil moisture in the in−line operational assimilation cycle. The initial conditions at 0000 UTC 1st May 2002 were linearly interpolated from the 24−km grid of the regional atmospheric system to the 10−km off−line grid.

The second off−line assimilation cycle (OFF2) is identical to OFF1, except that NEXRAD level III data was used to upgrade the precipitation forcing. Essentially, the radar 3−hourly precipitation accumulations were directly used when and where the data was available; model results (same as in OFF1) were used to fill the regions with no radar data. The differences between OFF1 and OFF2 should thus be entirely due to the different precipitation forcing. In the next section, we present preliminary results obtained with the three assimilation cycles (IN, OFF1, and OFF2).

3. RESULTS

The soil volumetric water content of ISBA's deep (i.e., rooting depth) reservoir at the end of the assimilation cycle, i.e., 0000 UTC 1st September 2002, is shown in Fig. 1 for the three experiments. The main features of soil humidity over the continental United States are fairly similar for the three experiments, with very dry soils in the western portion of the country,

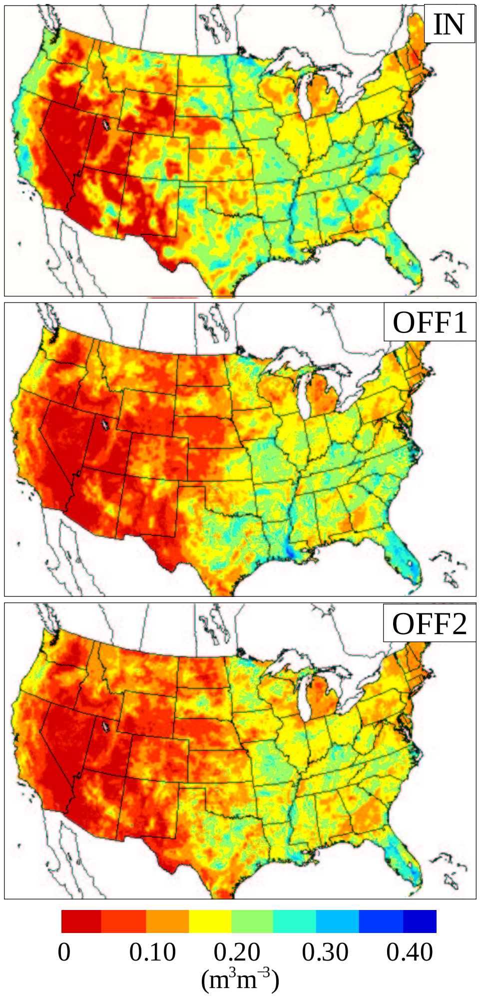

Fig. 1. Soil volumetric water content (m^3m^{-3}) at the end of assimilation cycles (0000 UTC 1st September 2002).

and more humid soils in the eastern half. There are nevertheless significant differences between the three humidity fields, such as drier soils for the central portion of the continent for the two off−line experiments, which will be discussed in the rest of this section.

3.1 In−line analysis increments

Because the atmospheric forcing that was used to drive the first off−line cycle was directly taken from the operational regional weather forecast model (in which the in−line surface assimilation is done), the main differences between the assimilation systems OFF1 and IN for the evolution of soil water should be directly related to the increments that were calculated in the in−line surface cycle based on screen−level model errors for air temperature and relative humidity.

Figures 2 and 3 show the differences of soil water between these two assimilation systems and the mean daily increments on soil water in the in−line operational assimilation system. It is clear that these two figures are complementary. For instance, there is a direct link between the negative differences (OFF1−IN) of soil water for the central US and the positive w_2 increments for the same region in the in−line operational assimilation cycle. Another large difference between the two systems is the more humid band along the west coast in the in−line system, which is related to positive soil water increments that are due to a problem in the low−level air humidity analysis along the west coast. In this region the effect of the more "marine" coastal measurements are spread too deep inland by the analysis procedure. The analysis increments elsewhere in the US are a mix of positive and negative tendencies.

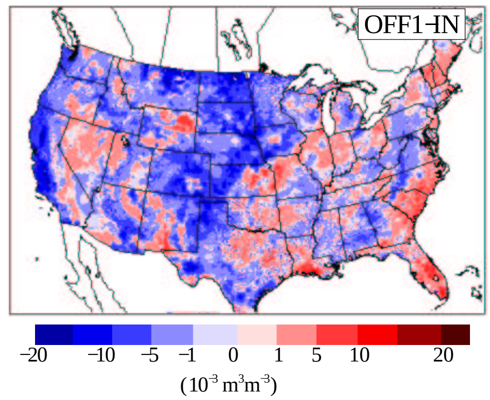

Fig. 2. Differences of soil volumetric water contents between the OFF1 and in−line assimilation cycles at 0000 UTC 1st September 2002.

For some reasons, the errors on low−level air temperature and relative humidity produced soil moisture increments that lead to a very different evolution of soil water in the off−line and in−line assimilation systems. These reasons are in part related to errors in the precipitation fields, which are discussed in the next section.

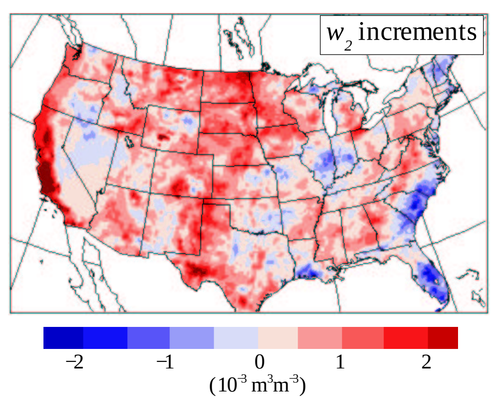

Fig. 3. Daily mean increments for the deep reservoir soil water of ISBA (i.e., w_2) in the operational in−line surface assimilation system.

3.2 Impact of radar data

The differences shown in Fig. 4 between the soil volumetric water contents at the end of the OFF1 and OFF2 cycles are due only to the different precipitation forcing for the two cycles (model precipitation for OFF1 and NEXRAD level III accumulations for OFF2).

It is interesting to note from Fig. 4 that the surface assimilation cycle forced with radar data produced more humid soils along a north−south axis in the central portion of the US, and drier soils for most of the Eastern US. It thus seems that the use of radar data produced a soil water field at the end of the off−line assimilation cycle that is in better agreement, at least for the central portion of the US, with the operational in−line soil water analysis.

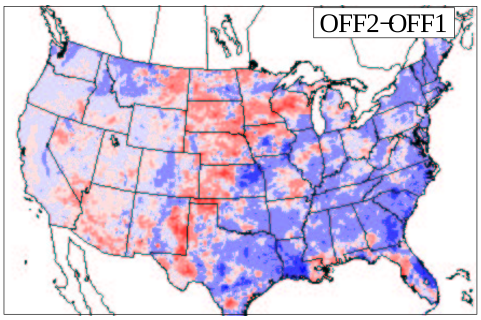

Fig. 4. Same as Fig. 2 but for the differences between the OFF1 and OFF2 off−line assimilation cycles.

Figure 5 shows the monthly mean precipitation forcing for the two off−line cycles. In agreement with the soil moisture differences shown in Fig. 4, the precipitation accumulations from the model (OFF1) are generally larger than the radar−derived accumulations (OFF2) for the Eastern US. Although more difficult to see from the two panels shown in Fig. 5, there is also evidence of the larger precipitation accumulations from radar along the north−south axis in the central US.

Previous evaluations of radar data (for summer 2001) have revealed that accumulations from the NEXRAD level III data seriously underestimated large precipitation amounts (not shown). It is not clear if the same problem will be found for the 2002 warm season period. Objective evaluation against measurements from surface stations will be shown at the conference for both the model−predicted and radar−derived precipitation accumulations.

4. NEXT STEPS

In the next few months, one of our main objectives will be to better understand the differences between the three assimilation systems, and to objectively evaluate the quality of the radar precipitation forcing. We will also attempt to improve the surface radiative forcing, which is another important factor that could explain the differences between the off−line and in−line assimilation surface assimilation cycles.

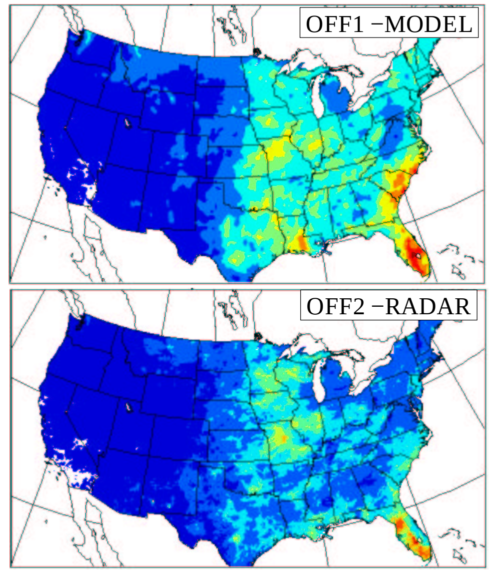

Fig. 5. Monthly mean precipitation forcing for the two off−line cycles for the warm season period (i.e., from 1st May to 31 August 2002).

The off−line system presented in this study is now ready to be used for data assimilation. One type of data that we will attempt to assimilate are infrared radiances from GOES, which are sensitive to the surface skin temperature. It will also be important to continue our use of screen−level observations to improve the analysis of soil water. For this, it may be necessary to include, in some way, a representation of the boundary layer in the off−line assimilation system. Eventually, data from sensors which are directly sensitive to soil moisture (e.g., L−band) should be considered in the assimilation process.

REFERENCES

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Bélair, S., R. Brown, J. Mailhot, B. Bilodeau, and L.−P. Crevier, 2003b: Operational implementation of the ISBA surface scheme in the Canadian regional weather forecast model. Part II: Cold season results. Accepted for publication in *J. Hydromet.*