JP2.13 Use of a Snow Prediction Scheme in a Mesoscale Realtime FDDA System.

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1. INTRODUCTION

A realtime Four Dimensional Data Assimilation (rt-fdda) system (Cram et al., 2001) using the nudging technique has been developed and running operationally over the Dugway Proving Grounds (DPG) in Utah, since the middle of 2000. It is widely accepted that the role of the land surface processes are of critical importance in modeling the boundary layer and providing the lower boundary conditions to the atmosphere. It was felt that modeling the snow depth coupled with a simple bucket soil moisture scheme would be necessary to enhance the performance of the rt-fdda system at the surface during the winter season. However, this raises some practical considerations namely the initializations of the snow and moisture fields on the meso-alpha and meso-beta scales.

Whilst daily snow analyses can be obtained from various sources such as NESDIS and Air Force on a daily basis, they are not readily available in time to ingest in the rt-fdda system. Moreover the analyses are of coarser resolution. The analyses are not adequate for the initialization of the nested domains with resolutions of 10 km and 3.3 km. The issue of initialization is even more problemic for the soil moisture initialization. The soil moisture analysis is not readily available since there are no routine soil moisture observations. This makes a proper soil moisture initialization procedure difficult.

During the wintertime, the presence of snow and change in soil moisture content have substantial impact on the local circulation. The accumulation and distribution of the snowfall forced by the upslope ascent over the complex topography of DPG enhances the drainage flows and modifies the surface fluxes.

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This paper highlights the improvement of the skill scores with the inclusion of the snow and soil moisture effects in a realtime operational rt-fdda system over DPG. It also points out the associated drawbacks of initializing the meso-beta scale using synoptic information in an operational setting.

2. A SNOW SCHEME

In it’s current implementation the simple scheme will characterize precipitation as snow over rain areas when air temperature is at freezing point. The snow will accumulate if the precipitation reaches the ground at a temperature of 0^oC or less. Conversely, snow melts when the ground temperature is above freezing or is lost through sublimation if the clear air above the ground is unsaturated. The land-surface characteristics, moisture, and thermal properties are adjusted accordingly over snow-covered grid boxes of the model.

The ground temperature is predicted using a uniform slab model following Blackadar (1976), and computing the surface heat budget. The resultant soil temperature is modified by the melting process. If enough snow is available to cool the soil temperature to 0^oC, then the soil temperature is reset to freezing, otherwise not enough is available and all is melted. An equivalent amount of energy used for melting is lost and the ground is cooled proportionately.

Several weaknesses exist in this simple approach. For example, it is assumed that the snow cover is uniform across the grid cells, and it also makes no distinction between fresh snow and older snowfall. Though the surface landuse properties (albedo, thermal capacity, etc.) are modified in snow-covered regions, there is no differentiation made to account for the snow age.

3. SNOW INITIALIZATION

The rt-fdda MM5 snow field is initialized on a weekly basis using the NCEP mesoscale ETA-212 analysis of the water-equivalent snow depth field. This analysis, which has a grid resolution of about 40 km, is horizontal interpolated to the MM5 grids on 30-km, 10-km, and 3.3-km for domains 1, 2, and 3, respectively (Cram et al., 2001). While domain 1 is of comparable resolution, the nest domains are not. In initializing the nested domains, the smoothed snow data on the coarse domain is interpolated to the nested domains.

The land-surface characteristics such as moisture availability, thermal capacity, albedo, and others are adjusted to be consistent with the presence of snow at these initialized grid points. The physical snow depth is assumed to be 10 times the water-equivalent snow depth.

The use of the coarse ETA snow information to initialize the nested domains has the adverse effect of spreading the snowline too far from the actual sources. In an attempt to mitigate such problem of overspecification, the snowline is determined through a simple algorithm which uses the previous day's observed maximum temperature distribution, the terrain height within the particular domain, and a critical temperature presently set at 4^{o}C. The nested terrain information, which has higher peaks and better definition of the physical landscape than in the smooth ETA data, helps to define the mesoscale distribution. While this analysis helps to delineate the snowline and discriminate the snow at the peaks from the valleys, it does not redistribute the analyzed snow data. A further analysis of downscaling is necessary and some knowledge of the climatology of the snow distribution of the region will be required.

4. FDDA SYSTEM AND EXPERIMENT DESIGN

The rt-fdda system described in Cram et al. (2001) performs eight 3-h analysis cycles in a 24-h period. A short 6-12h free forecast is done after each 3-h analysis cycle. The previous MM5 forecast provides the first guess fields to which the incoming observations are quality controlled. The observations are ingested continuously into the MM5 model in a consistent manner via the nudging technique.

In the experiment setup, two rt-fdda systems with identical configurations and MM5 model options were run in parallel this past winter season. One system included the prediction of snow and a simple bucket soil moisture scheme, while the other did not. The goals were to monitor and assess the system's performance in realtime while gaining experience on the meso-beta scale in an operational setting.

The model output forecasts are interpolated to station locations and evaluated against the quality-controlled observations.

5. RESULTS

The mean statistics (Table 1) over all domains for the two and half months beginning January 1 2001, show a marked improvement of the system with snow and soil moisture modifications over the system without the modifications and its related effects. The bias in both the temperature and moisture fields at the surface is substantially reduced and in the case of the temperature, the bias is reduced by more than half in the runs with snow for the 6-h forecast.

Fig. 1a shows the Air Force analysis of the snow depth field for Jan 30 2001, at 0000 UTC over North America. The Air Force snow depth model (Kopp and Kiess, 1996) uses the SSM/I information as well as snow reports over land and climatology to produce a snow depth and sea ice global analysis on a 48-km resolution. Fig. 1b shows the corresponding water equivalent snow depth distribution over the MM5 30-km domain. The two figures show good agreement, with the snow amount largest over snow peaks along the Rockies, and reduced amounts over the lower elevations and the mid-west plains. The southern extent of the snowline over Nevada, Arizona, and New Mexico are comparable. The snow amounts over eastern California, Oregon, and Washington are also in fairly good agreement.

Although the mean statistics over all domains (Table 1) show improved predictive skills with the inclusion of snow effects, the daily monitoring revealed some undesireable effects of the initialization of snow on the high-resolution domains during the weekly cold start. The cold start of the rt-fdda system is done on Saturday morning using the 12Z ETA-212 analyses having a grid spacing of 40 km (refer to Cram et al., 2001 for more details). The smooth ETA snow data is interpolated to the MM5 10-km and 3.3-km grid meshes and has an undesirable effect of filling in the valleys and extending the snowline over snow-free areas. This has an adverse-

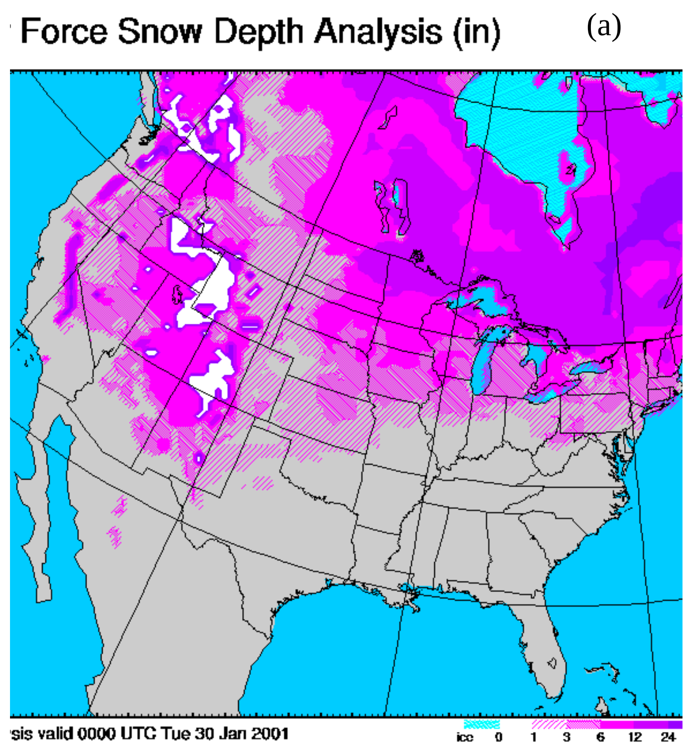
Table 1: Two and half month mean statistics of Temperature (C) and specific humidity (g/g) of the ATEC RT-FDDA system over the whole domain for the 2001 Wintertime

		BIAS		RMSE		MAE	
FCST (h)	VRBL	NSO	SNO	NSO	SNO	NSO	SNO
1	T	.833	.505	2.96	2.95	2.18	2.19
	Q	-.413	-.323	1.33	1.28	0.73	0.71
2	T	.844	.469	3.12	3.04	2.28	2.27
	Q	-.421	-.312	1.24	1.15	0.76	0.71
3	T	.889	.442	3.23	3.13	2.39	2.34
	Q	-.455	-.332	1.38	1.31	0.81	0.75
4	T	.921	.445	3.32	3.16	2.44	2.38
	Q	-.469	-.323	1.43	1.33	0.82	0.76
5	T	.934	.447	3.39	3.24	2.94	2.41
	Q	-.416	-.280	1.31	1.84	0.81	0.75
6	T	.947	.404	3.43	3.25	2.55	2.44
	Q	-.477	-.313	1.430	1.30	0.85	0.78

effect and produces discontinuities in the FDDA cycle at cold start. The problem is worse when there is a thawing period over the nested domains prior to cold start.

The system tries to melt the excessive snow introduced during the cold start and subsequently lags and is outperformed by the system without the snow effects included. Furthermore, since the moisture availability, the thermal capacity, and other surface characteristics are modified by the presence of snow on the ground, the local circulations are severely hampered during that period of adjustment.

Following a thawing period on March 6 2001, the snow distribution on the 3.3-km domain was limited to the high peaks on the fine-mesh domain where the terrain features are resolved (Fig 2a). The snow-capped peaks over the Wasatch and Deep Creek range to the southwest are clearly visible. However, at cold start time, (17Z cycle) the snow-free areas are instantly covered by as much as 1 in of new snow with the largest amount being along the inner boundaries where they intersect with the coarser domain. Fig. 2b shows the snow distribution 2 h into the FDDA cycle after the cold start, valid at 1400 UTC Mar 6 2001. The snow coverage has



(a)

(b)

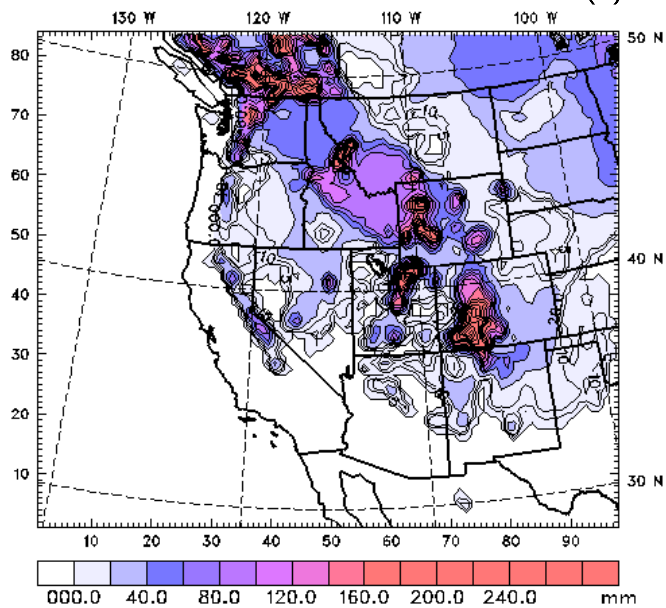


Figure 1. The Air Force Snow Depth Analysis (in) valid 0000 UTC Jan 30, 2001, and the 57-h RT-FDDA of the 30-km Water Equivalent Snow Depth (mm) valid at 2100 UTC Jan 29 2001.

spead over a large area inside the 3.3-km domain where no snow existed some 2 h earlier.

6. CONCLUDING REMARKS

Our preliminary results show that the inclusion of a simple snow scheme enhances the performance of the rt-fdda system over DPG during the wintertime. For a two and half month period the mean bias in surface temperature is reduced by more than half for a 6-h forecast over a similar system without a snow prediction and soil moisture availability scheme. The associated modifications to the surface characteristics impact directly onto the moisture fields. The errors in the surface moisture field are significantly reduced.

The initialization of the snow field on the meso-beta scale needs improving if the potential benefits for the short-term prediction are to be realized consistently. It is found that the system can lagged behind one without a snow and soil moisture prediction when the fine resolution domain is not properly initialized at cold start. The smoothed ETA data from the coarser resolution is unable to give an adequate description of the snow distribution on the finer MM5 grids. Some of the errors in skill scores were attributed to the initialization of the water equivalent snow depth field obtained from the National Center for Environmental Prediction (NCEP) mesoscale ETA-212 analyses (40 km) to the finer MM5 (10 and 3.3 km) model grids.

An approach to determine the snowline as a function of the previous day's maximum temperature observations and the local topography is being tested. The snowline helps to refine the amount and areal coverage obtained when interpolating the coarse ETA analysis to the finer MM5 meshes. The snowline is determined based on a critical temperature. A further refinement through downscaling technique is being pursued.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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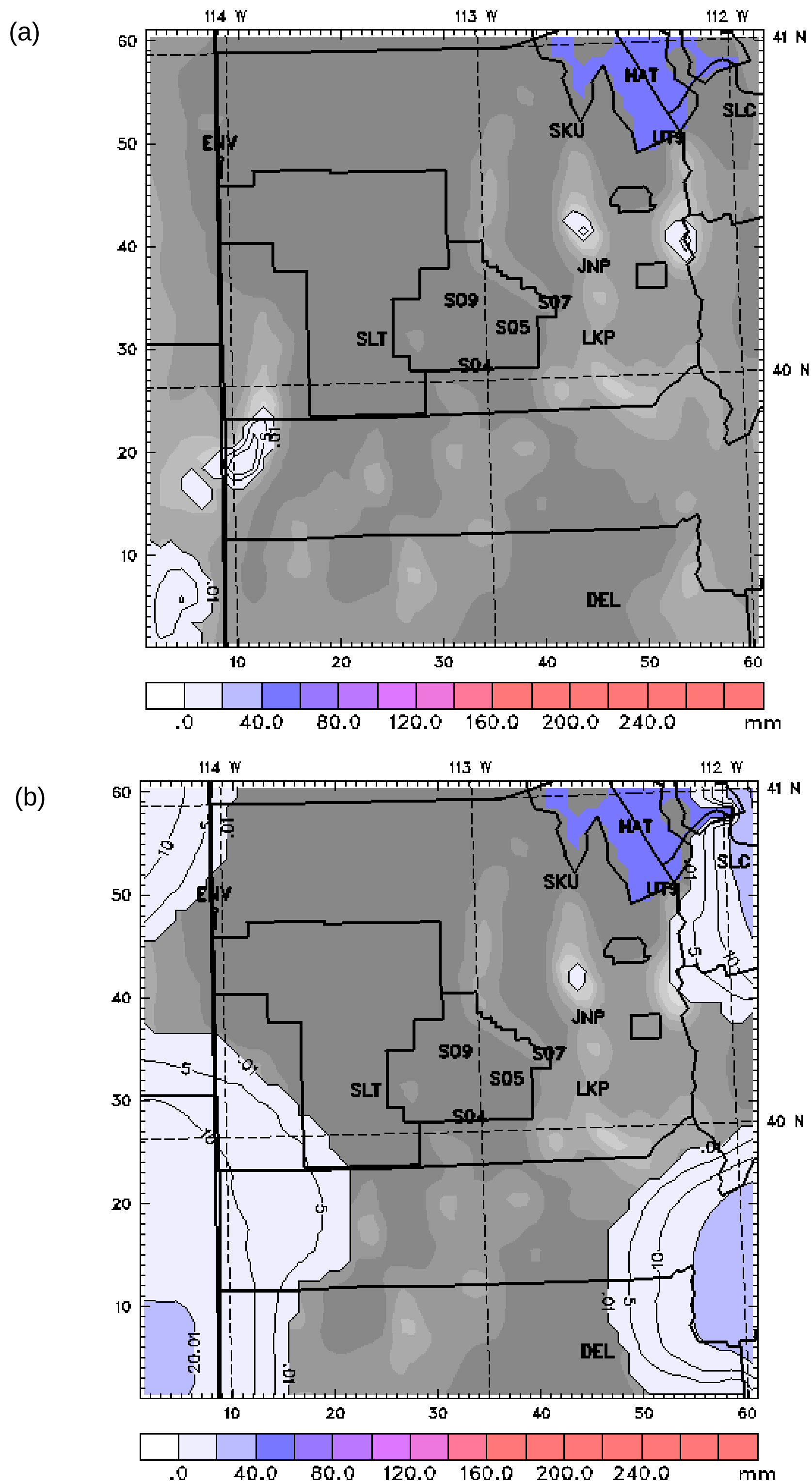

Figure 2. Map of Water Equivalent Snow field (a) after 78-h FDDA (before cold start) valid at 1100 UTC Mar 6 2001, and (b) after 2-h FDDA (after cold start) valid at 1400 UTC Mar 6 2001.