AN IMPROVEMENT IN MOISTURE FLUX OVER SNOW

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1. INTRODUCTION

AFWA reported a problem in early March 2007 in which they were seeing low forecast visibility in snow-covered regions due to high relative humidities, particularly during day-time hours. This impacted several domains including the ConUS. The specific humidities over snow cover were unrealistically high in places. In fact, values as high as 5 g/kg were seen, which is well above the saturation value at 0 deg C.

2. SOLUTION

Several things were tried to fix this problem, including improving the treatment of saturation humidities and latent heat over ice surfaces, and while these improvements also made it into the final code, they had minor impact on the problem.

The problem turned out to be in the computation of potential evaporation with the Penman method. The potential evaporation determines the upper limit for surface evaporation, which is effectively the actual evaporation amount when over snow cover, since it is like a saturated surface. The Penman potential evaporation has two terms. The first is just proportional to the subsaturation of the air, and gives some idea how much more water vapor the air can hold. The second is dependent on the forcing of ground temperature, and represents a change in saturation vapor pressure, and hence in potential evaporation, as the ground heats or cools. This second term was the problem over snow cover, because it considers that the ground temperature will change with forcing such as solar radiation, while actually when the ground temperature reaches freezing, it cannot warm any further with snow cover because the heat goes into melting instead until the snow cover is gone. The model correctly restricts the ground temperature from exceeding 0 Celsius, but the Penman potential evaporation calculation proceeds as though there is no such restriction.

The key change was the addition of this line

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IF(T1 .GT. 273. .AND. SNOWC(I,J) .GT.
0.)DQSDT2=DQSDT2*(1.-SNOWC(I,J))
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where T1 is the ground temperature, SNOWC is the snow cover fraction, and DQSDT2 is the rate of change of saturation vapor pressure over ice with temperature.

The second Penman term is directly proportional to DQSDT2. By reducing DQSDT2 to effectively zero for complete snow cover (SNOWC=1.), we prevent this term from acting in conditions where there is snow cover and the ground temperature is near freezing. This means that the potential evaporation does not rise unrealistically with solar forcing when there is snow cover, and that solves the problem with the high humidities above snow in the day-time. Note also that for fractional snow cover this restriction on DQSDT2 ramps in proportion to the fraction to allow for the normal potential evaporation over bare ground.

In summary, the primary effect of this fix is to restrict evaporation to be consistent with a non-changing ground temperature that exists when there is snow cover at 0 C. Changes in results should therefore be seen only in areas where there is snow cover and the ground temperature is at 0 C, and where there is significant forcing (such as solar radiation). Other regions should be unaffected.

3. RESULTS

Here we present a sample result to show the effect of the changes on the low-level atmospheric moisture fields. Figure 1 shows that the regions that had 5 or more g/kg (yellow shades) at 18Z in the day-time in the original code (top left), no longer exist with the changes described here (top right). The area of difference (bottom) is essentially the snow-covered area. The effect on the temperature (not shown) is 0-0.5 degrees warming in these areas. With this reduction in relative humidity, a better diagnosed visibility will be produced. A similar plot earlier in the morning at 15Z (not shown) has much smaller differences, and no large mixing ratio values, consistent with the idea that the problem results from day-time solar forcing in this case.

4. ACKNOWLEDGMENTS

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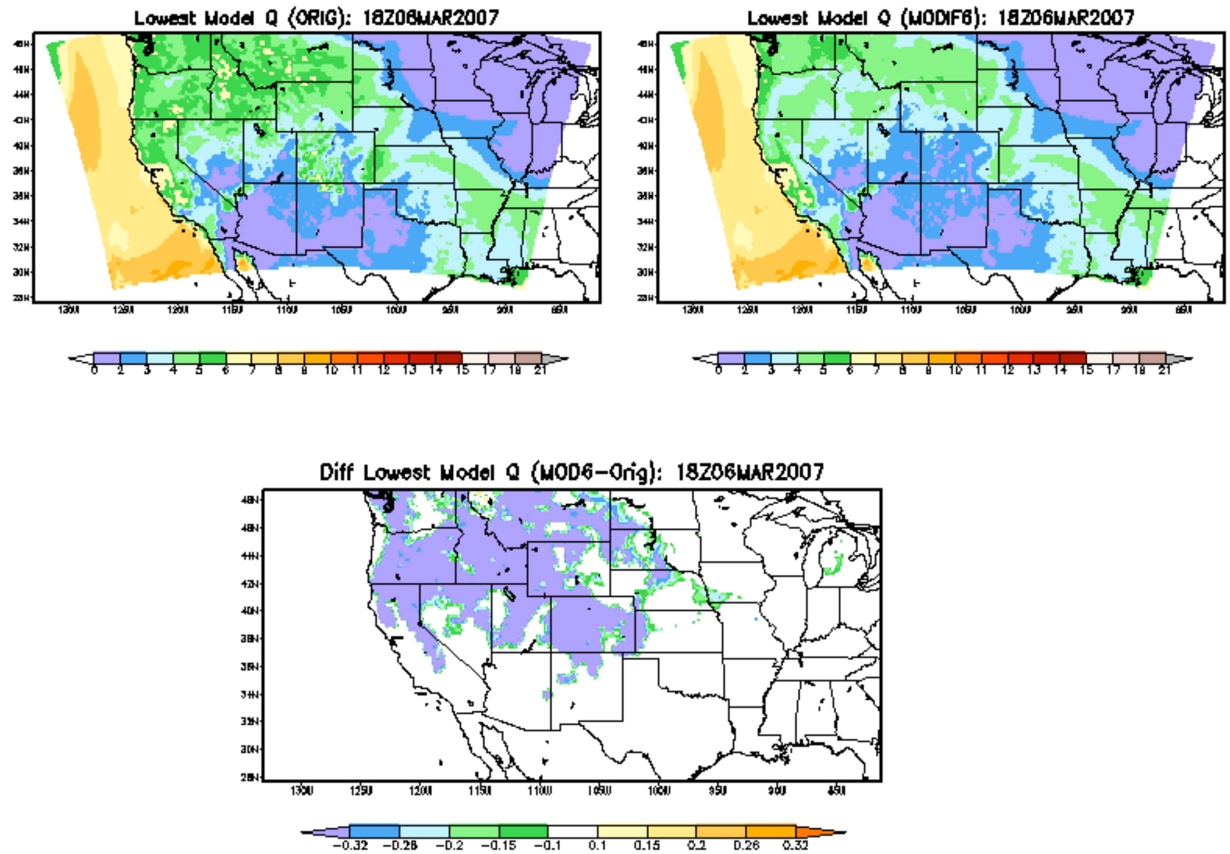

Figure 1. Lowest model level water vapor mixing ratio in a 6-hr forecast verifying at 18Z 6th March 2007 for (top left) the original code, and (top right) the new code, and (bottom) the difference between these two.