Impact of vegetation cover estimates on regional climate forecasts

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1. INTRODUCTION

Numerical Weather Prediction and Regional Climate Models often rely on temporally averaged climatologies of fractional vegetation cover. These surface properties (in addition to soil temperature and moisture, and ground fluxes) are typically parameterized in a coupled Atmospheric Model and Land Surface Model (LSM) for estimating the exchange of energy and moisture between the Earth's surface and the atmospheric boundary layer. Specifically, LSMs use vegetation fraction to aid in the partitioning of latent, sensible, and ground heat fluxes for a heterogeneous vegetated surface. These exchanges and partitions between the land and atmosphere play a critical role in many hydrometeorological processes. The variations in land surface properties can influence the distribution and amount of precipitation (Pielke et al. 1998). Owing to the importance of fractional vegetation cover in hydrometeorological processes, over time these temporally averaged climatologies may not be representative. This problem arises as a result of ongoing changes in land cover use, for example expanding agriculture, or by areas affected by drought or other types of forcing on the land surface. Identifying the impacts of vegetation anomalies from climatologic normals may be more recognizable in regions that are on the knife edge between semiarid and more humid climate regimes.

Here, we shall demonstrate the impact of altering the monthly fractional vegetation cover on regional forecasts of weather and climate for the Northern Great Plains. Employing the Applied Research Weather Research and Forecasting Model (WRF-ARW, Skamarock et al. 2008), comparison of simulations with the "default" and remotely-observed vegetation cover will be used to assess the impact on regional forecasts. WRF simulations were done for the growing season of the wet year 2007. The goal is to generate regional climate simulations, which are consistent and sensible representations of the land surfaces' and, in turn, the atmosphere's behavior.

2. METHOD

The model domain (150x150) was placed over the Northern Great Plains (Figure 1) with 10km grid spacing. WRF's new version 3.0.1 was run from the first of March to the first of November for 2007. The boundary conditions for WRF were provided by the North American Regional Reanalysis (NARR) with 32.5-km grid spacing at three hour intervals (Mesinger et al. 2006). WRF was run using the WRF Single-Moment 6-Class (WSM6) microphysics scheme (Hong et al. 2006), the NOAH land surface model (Chen and Dudia 2001a, b), the YSU planetary boundary layer scheme (Hong et al. 2005), the New Grell (G3) cumulus scheme, and the CAM scheme (Collins et al. 2004). Our configuration of WRF, in regional climate mode, utilizes a loop of individual simulations each 24 hours long, which were initialized from the restart files of the previous day.

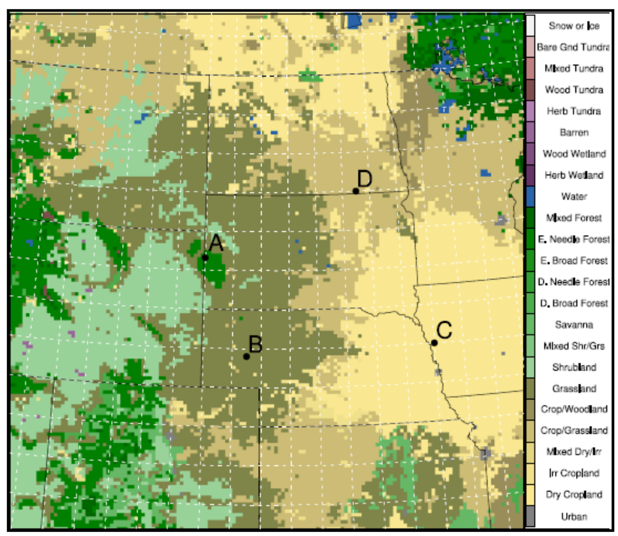

Figure 1: Model domain and land categories.

The remotely observed data for creating the vegetation fraction product was obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite, which has a 1-km resolution at an interval of sixteen days. These data are then put through an algorithm (Jiang et al. 2006) to compute the scaled vegetation index (SDVI) where:

$$SDVI = \frac{DVI - DVI_s}{DVI_v - DVI_s}$$

In this context, DVI is the difference vegetation index given by the difference in the near infrared and red reflectances. SDVI is the difference between bare soil DVI (DVI_s) and dense vegetation DVI (DVI_v). Jiang et al. (2006) showed that SDVI can be directly used for vegetation fraction since SDVI and the vegetation fraction are equivalent in value. SDVI has advantages over using the normalized difference vegetation index (NDVI), such as the insensitivity of DVI to changes of vegetation fraction of shadowed soil and the linearity of SDVI. Jiang et al. (2006) also suggest that caution be used when extending the SDVI approach to forest canopies, which are inherently more complex, due to further analysis needed in assessing the accuracy of SDVI.

Prior to swapping WRF's default vegetation fraction the MODIS vegetation fraction must be up-scaled from 1 km to the model's grid scale. WRF must also be reconfigured to run on a "36 month" year (permitting a faster temporal update of vegetation fraction made available through the MODIS data sets) to utilize the MODIS vegetation fraction dataset. Once the initial run of WRF with the default vegetation fraction was complete, WRF was run again using the MODIS data with the same parameterization schemes. Thus, the only difference between the two simulations is the vegetation fraction cover.

3. RESULTS

The regional climate simulations were compared to the NCEP Climate Prediction Center (CPC) precipitation data and to each other to assess the impact of altering the vegetation fraction cover. Comparison of the regional total fractional vegetation cover (Figure 2) readily displays the differences between the MODIS and Default vegetation.

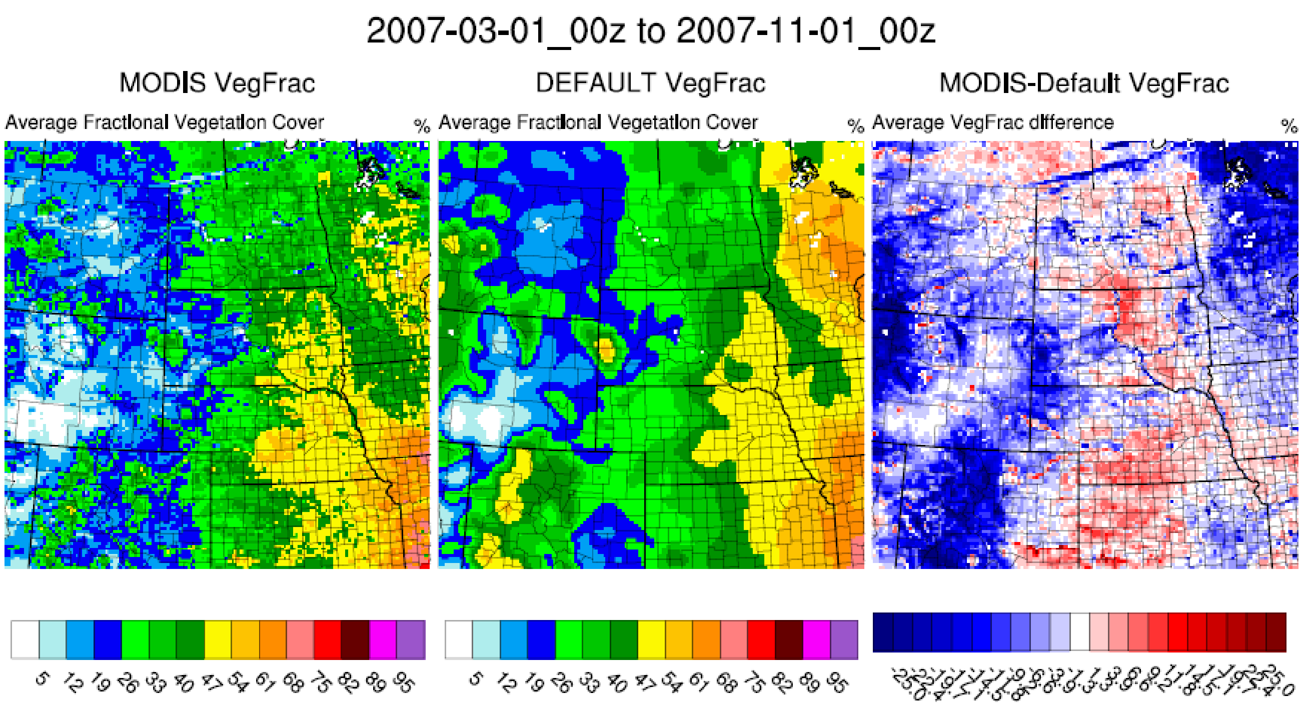

Figure 2: Vegetation fraction from WRF scenarios: MODIS (left), Default (center), and the difference between MODIS and Default. Displayed values are the vegetation covers averaged over the simulation.

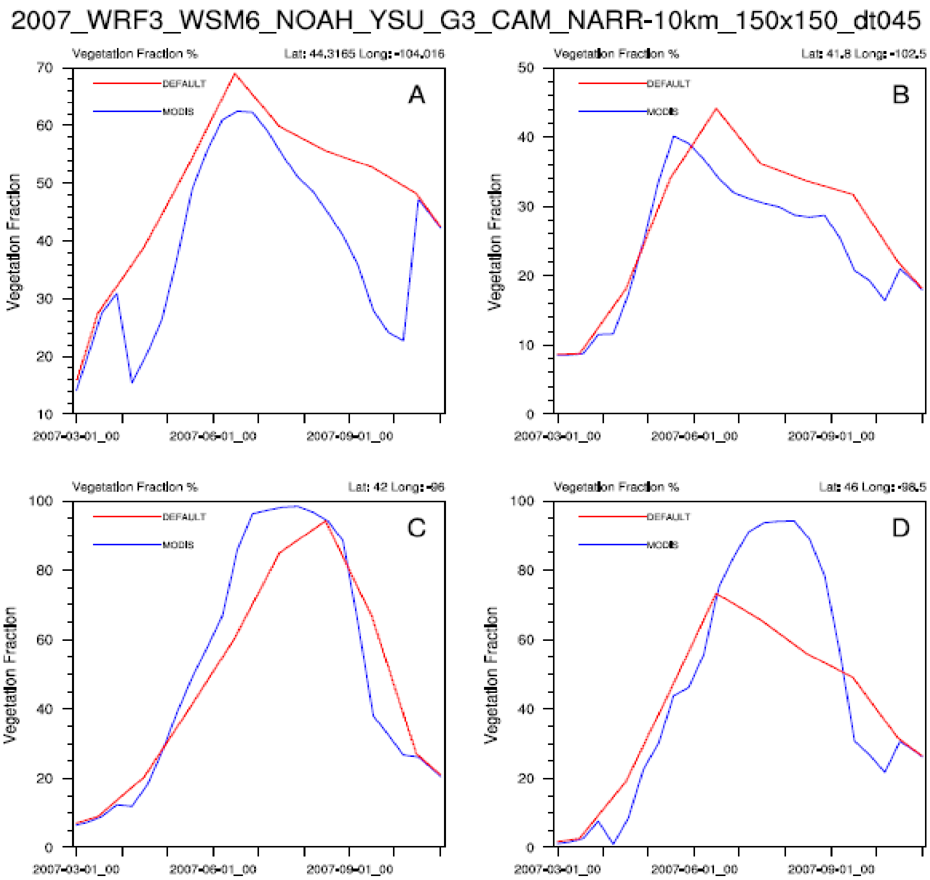

Figure 3: Vegetation fraction vs. Time for MODIS (blue) and Default (red) at vegetation regimes A, B, C, D as in Figure 1.

The total Default fractional vegetation is smoother and more continuous than the MODIS vegetation fraction. Subtracting the Default vegetation fraction from MODIS (Figure 2: far right panel) indicates the areas where the Default was greater than MODIS (blue, negative values), where the Default was less than the MODIS (red, positive values), and where the Default and MODIS are equal (white). A large swath of lower vegetation anomalies (blue) starts from the Colorado Rocky Mountains and extends into western Nebraska and South Dakota and another runs down Minnesota into Iowa. The areas of higher vegetation anomalies (red) are generally confined to a swath in the center of the domain extending through western Kansas and into eastern North Dakota.

Inspecting both the Default and MODIS vegetation fraction varying with time (Figure 3) at points A, B, C, D (as in Figure 1) with land categories of forest, grassland, irrigated cropland, and dry cropland, respectively, indicates the rise and fall of vegetation fraction through the growing season. Due to the finer resolution the MODIS data will be different from the Default. At the forest point (A) the Default and MODIS are similar until after reaching the maximum vegetation fraction, where the MODIS decreased rapidly. The MODIS vegetation faction for the grassland point (B) was less than the Default and peaked sooner, whereas the irrigated and dry cropland points (C, D) peaked at larger vegetation fractions than the Default.

Assessing the impacts of these differences between the Default and MODIS vegetation fraction was done by comparing the WRF precipitation output against the CPC precipitation data. Monthly total precipitation for both scenarios generally showed good conformity with each other. Comparisons of the CPC precipitation and the scenarios demonstrated reasonable agreement overall, with locations and intensities generally the same. Differences between the scenarios for total simulation precipitation (Figure 4) were also in good agreement, where the largest differences in changes in a single thunderstorm's location and intensity. Overall compared to CPC there was a slight wet bias in both scenarios, but the MODIS bias was slightly less than the Default.

4. CONCLUSION

Temporally averaged climatologies used for regional forecasts of weather and climate can become unrepresentative due to land cover changes. This was demonstrated for the 2007 growing season over the Northern Great Plains, where altering the Default vegetation fraction with the eastern half of the domain were attributed to remotely observed MODIS vegetation fraction produces similar regional forecasts. The precipitation bias for the MODIS fractional vegetation cover was slightly less wet as compared to the Default and CPC.

Future work includes expanding the model domain to include stronger synoptic forcing to the north and stronger influence of moisture transport from the Gulf of Mexico and to continue running the simulations for dry and average years for both scenarios.

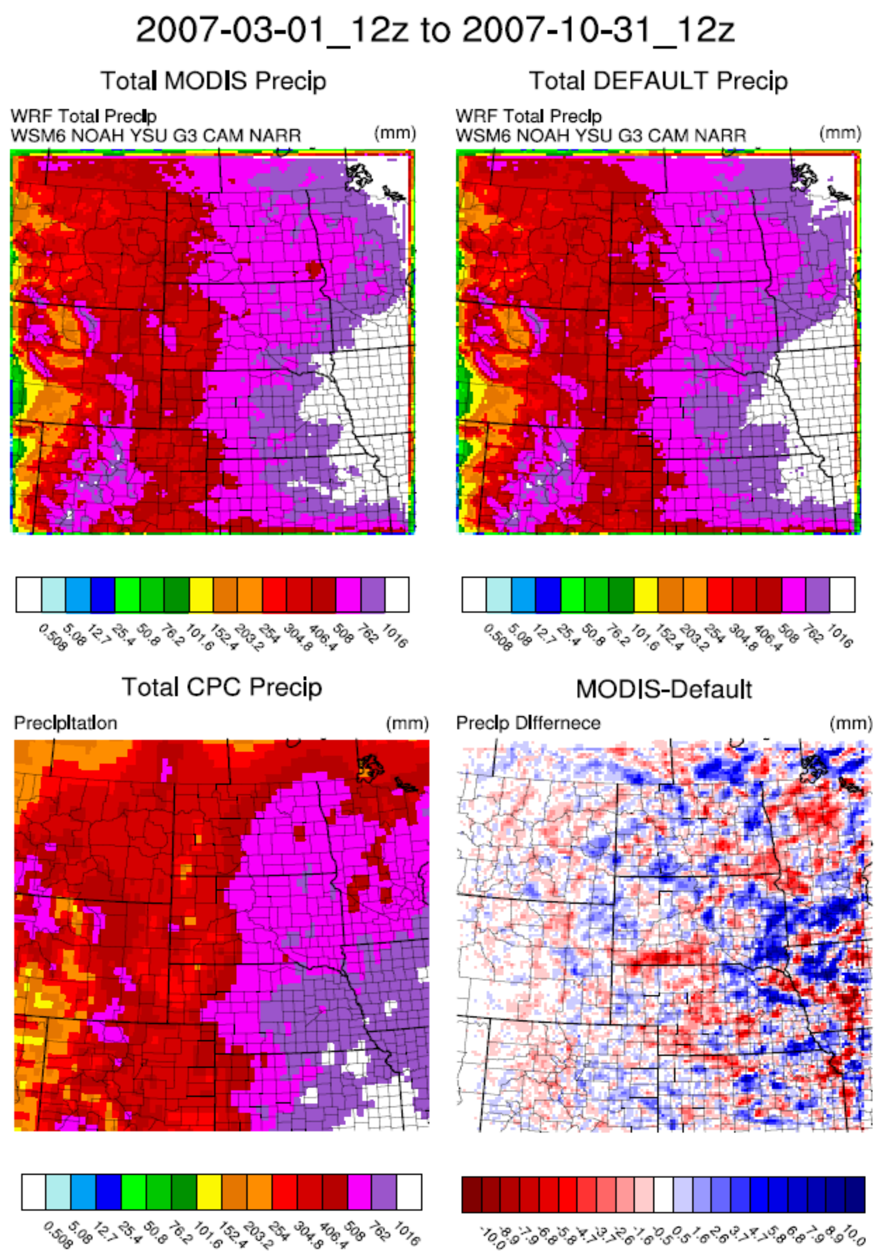

Figure 4: Total precipitation, MODIS (top left), Default (top right), CPC (bottom left), Difference (bottom right).

5. ACKNOWLEDGEMENTS

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