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Effects of vegetation dynamics on evapotranspiration and soil moisture in northwestern Mexico

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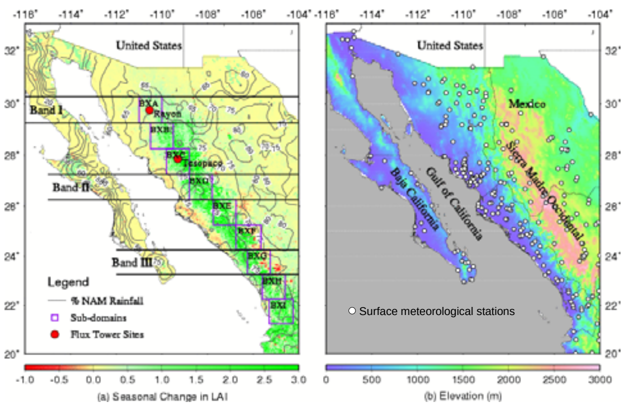
❶ Summary

Most land surface models use a fixed seasonal vegetation cycle and are unable to fully capture the spatiotemporal changes in vegetation in northwestern Mexico, a region characterized by an abrupt increase in rainfall and ecosystem green-up during the North American monsoon (NAM). In this study, time-varying leaf area index (LAI) and a fixed seasonal LAI cycle, both inferred from the Moderate Resolution Imaging Spectroradiometer (MODIS), were compared as inputs to the Variable Infiltration Capacity (VIC) model over northwestern Mexico during 2001-2008. Model results for the two sets of simulations were compared with latent heat fluxes observed by two eddy covariance tower sites for three summer periods. The results show that both vegetation greening onset and dormancy dates vary substantially from year to year with a range of more than half a month. Using the fixed season LAI cycle, the model tends to under- (over-) estimate evapotranspiration (ET)and over- (under-) soil moisture (SM) when vegetation greening occurs earlier (later) than the mean greening onset date. The discrepancies in ET were large, especially during a period of approximately two week at the beginning of the monsoon. The effect of vegetation dynamics on ET estimates was about 10% in the Sierra Madre Occidental (SMO) and 30% in the continental interior east of the mountain range.

❷ Study Area



❸ Vegetation Greening

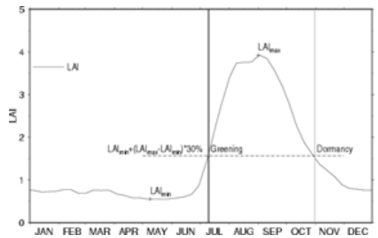
Rapid vegetation greening during NAM

Before vegetation green-up

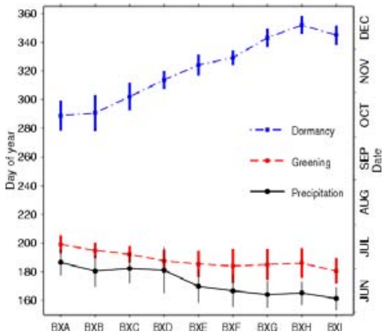
After vegetation green-up

Photographs courtesy of Julio C. Rodriguez, Universidad de Sonora.

MODIS LAI variations



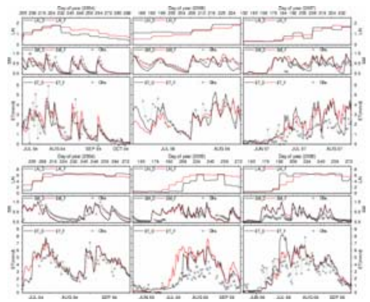
Schematic of the definition of vegetation greening onset and dormancy.



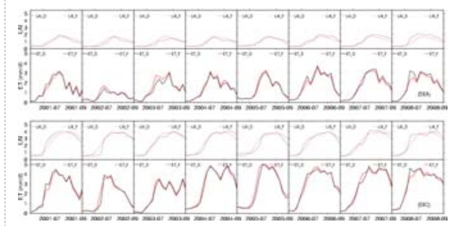
Monsoon precipitation onset date, vegetation greening onset date, and vegetation dormancy date from 2001 to 2008 for the nine sub-domains, arranged from north (left) to south (right). The bars indicate the standard deviations of the dates.

The greening onset date varies substantially from year to year, with a larger range of dates in the south (about one month) as compared to the north (about half a month). The range of the dormancy date is larger in the north (about one month) than in the south (about half a month).

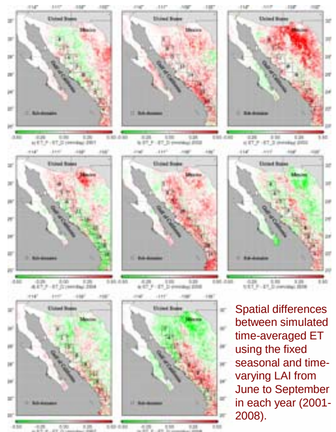
❹ Results



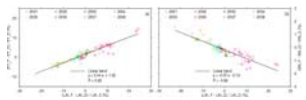
Comparisons of simulated and observed ET and SM at the Rayon site during DOY 199-290 in 2004,184-227 in 2006 and 152-240 in 2007 (upper three panels), and the Tesopaco site during DOY 192-275 in 2004, 151-274 in 2005 and 151-275 in 2006 (lower three panels). SM was normalized and scaled to [0, 1]. Shown are daily ET estimates (ET_D) and SM estimates (SM_D) using the time-varying LAI (LAI_D); and ET estimates (ET_F) and SM estimates (SM_F) using the fixed seasonal cycle of LAI (LAI_F).



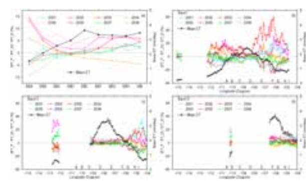
Comparisons of the 8-day ET estimates (ET_D) using the time-varying LAI (LAI_D) and ET estimates (ET_F) using the fixed seasonal cycle of LAI (LAI_F) from June to September of 2001-2008 for the sub-domains BXA and BXC.



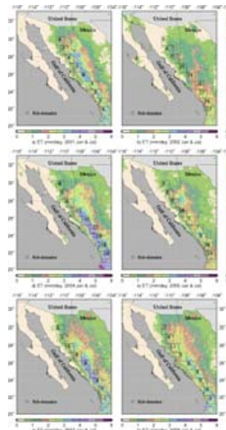
Spatial differences between simulated time-averaged ET using the fixed seasonal and time-varying LAI from June to September in each year (2001-2008).



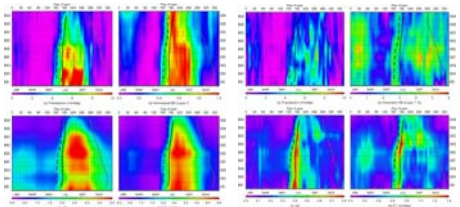
Relationship between the relative error of LAI and the relative errors of: (a) ET and (b) SM from Jun to Sep across the nine sub-domains in each year.

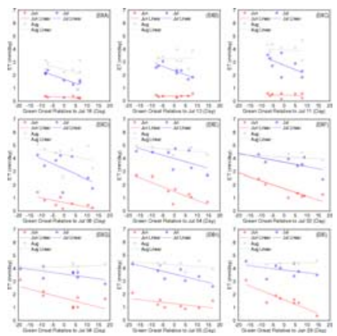


Relative errors of VIC-estimated ET and the seasonal mean ET (mm day-1) at the nine sub-domains (a), and along three longitudinal transects at the latitude bands.



Estimated mean ET during June and July (mm day-1) using the time-varying LAI for each year (2001 to 2008).





Mean 8-day precipitation (a), soil moisture at the top soil layer (b), LAI (c) and ET (d) using the time-varying LAI from 2001 to 2008 for the nine sub-domains. (left left) Interannual standard deviation of 8-day precipitation (a), soil moisture at the top soil layer (b), LAI (c) and ET (d) . (left) Relationship between the mean ET from the time-varying LAI cycle within each month (June, July and August) from 2001 to 2008 and the greening onset dates (expressed relative to the mean greening onset date) for the nine sub-domains. (right)

❺ Conclusions

VIC model with a fixed seasonal cycle of LAI tends to under- (over-) estimate ET when the vegetation greening comes earlier (later) than the mean greening date. The VIC model with fixed seasonal cycle of LAI could induce about 10% bias in ET estimation at the western slopes of the SMO and about 30% bias in ET estimation in the interior continental regions east of the SMO.

❻ References

Tang et al. Links between vegetation, evapotranspiration and soil moisture in northwestern Mexico during the North American monsoon, Journal of Climate (submitted).
Vivoni et al., 2008: Observed relation between evapotranspiration and soil moisture in the North American monsoon region, Geophys. Res. Lett., 35, L22403.
Vivoni et al., 2010: On the spatiotemporal variability of soil moisture and evapotranspiration in a mountainous basin within the North American monsoon region, Water Resour. Res., 46: W02509.