Introduction

Heterogeneous land surface conditions are essential components of land-atmosphere interactions in regions with active topography and the potential for effective convective precipitation formation. Yet, due to their high complexity, hydrologic processes over mountainous regions are not well understood, and are usually parameterized in simple ways within coupled atmosphere modeling frameworks. With the improving model physics and spatial resolution of numerical weather prediction models, there is an urgent need to understand how land surface processes affect local and regional meteorological processes. In the North American Monsoon (NAM) region, the summer rainy season is accompanied by a dramatic growth of mountain ecosystems that show spatial-temporal variability in vegetation which is anticipated to impact the conditions leading to convection, mountain-valley circulations and mesoscale organization. In this study, we present results from a detailed analysis of a high-resolution (1 km) land surface model (LSM, Noah-MP/WRF-Hydro), a large, mountainous watershed of the NAM region, the Rio Sonora (250 km²) in Mexico. In addition to capturing the spatial variations in terrain and soil distributions, recently-developed features in Noah-MP/WRF allow the model to read time-varying vegetation parameters derived from remotely-sensed vegetation indices. To fully evaluate the model performance, the model results are compared against ground observations and remote sensing products at different spatial resolution. In addition, NLDAS LSM outputs are used as benchmarks to verify water budget estimates at basin-scale. Finally, we focus attention on the impact of vegetation changes against different elevation bands on the diurnal cycle of surface energy fluxes to provide a baseline for future analyses of mountain-valley circulations using a coupled land-atmosphere modeling system.

Study Region

The Rio Sonora River system is a large river basin oriented from north to south in northern Sonora, Mexico. Excluding water demands for urban, industrial, and agricultural uses, increase competition for the already scarce water supply. As the primary water source supply for large and expanding cities and agricultural land in this region, the North American Monsoon rainfall contributes to about 70% of the total annual rainfall.

 Characteristics of the study region.

- High spatial variability of terrain conditions
- Semi-arid ecosystems organized along elevation
- Rapid land cover change during summer monsoon
- Sparse ground observations

Noah-MP/WRF-Hydro Evaluation

(A) Noah-MP/WRF-Hydro setup

- 1 km Noah-MP SM running on a 10 km resolution grid
- 100 km and channel routing grid
- 650 m soil classification from INEGI
- 10-second land cover classification from USGS
- 18-degree meteorological forcings from NLDAS
- Time-varying 250 m vegetation fraction parameter from MODIS NDVI product

(B) Noah-MP/WRF-Hydro evaluation at regional stations and basin scale

- Model output was evaluated against multiple observations at point scale and basin scale, including soil moisture, ET, and LST
- Model showed reliable performance in representing general observations and remote sensing estimations

(C) Model inter-comparison with NLDAS land surface models

Given the limited coverage of ground observation, the ability of the model to compute water budget at regional scale is tested by computing with three LSMS using data from the North American Land Data Assimilation System (NLDAS) project 2, including Noah, Mosaic, and VIC. Water budget estimated by WRF-Hydro and NLDAS LY.

Diurnal Cycle Analysis

(A) Diurnal cycle of surface energy fluxes

- Patterns in the diurnal cycle of energy fluxes over the basin
- Monsoon rainfall are concentrated in the afternoon and nighttime
- Diurnal changes in energy fluxes occur with monsoon onset, including increase in ZL and G, decrease in H and LST

(B) Time of peak of surface energy fluxes

- Monsoon rainfall peaks during the afternoon and nighttime across all ecosystems
- Shrubland produces its peak latent heat earlier in the day relative to other ecosystems, especially under non-rainy conditions
- Across all ecosystems, the peak time of latent heat is strongly related to plant transpiration
- The early peak of latent heat and transpiration over shrubland is potentially due to midday stomatal closure

Insights on Mountain-Valley Circulations

- Over the NAM region, latent heat reaches 200-300 W/m², and presents high spatial variability
- Shrubland produces less latent heat and peaks earlier in the day
- The difference in diurnal patterns of latent heat fluxes is potentially resulted from rain and ecosystem's phenology
- The time-varying spatial pattern of vegetation, precipitation, and heating over the diurnal cycle of surface energy and mountain-valley circulation need to be carefully considered in the coupled land-atmosphere modeling studies.

Findings and Future Work

- When prescribed with dynamic vegetation parameters, Noah-MP/WRF-Hydro can produce reliable hydrologic responses at both point and basin scale
- Semi-arid ecosystems organized along elevation presents distinct diurnal patterns of surface energy fluxes, and create large heating contrast
- Diurnal cycle of latent heat is strongly related to rainfall and ecosystem’s phenology, and can be used as an indicator of behavioral water-stressed ecosystems
- Future work will conduct fully-coupled simulations over the Rio Sonora River System to impact the up-scaled impact of land surface processes on mountain-valley circulation and diagnose key variables and threshold values for the development of corrective precipitation in mountainous regions.

References


Barroso, 2015: Hyperresolution hydrologic modeling in a regional setting using numerical weather prediction model with sand-scaled impact of land surface processes on mountain-valley circulation and diagnose key variables and threshold values for the development of corrective precipitation in mountainous regions.

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