Prediction of Seasonal to Inter-annual Hydro- Climatology Including The Effects of Vegetation Dynamics And Topography Over Large River Basins

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Introduction

- Physical and biological processes within the terrestrial biosphere and atmosphere are intrinsically coupled with the hydrological cycle.

- Vegetation plays a fundamental role in the exchange of heat and mass at the land atmosphere boundary.
  - Rainfall interception, radiative shading
  - Interdependence of soil moisture with plants affects latent heat fluxes to the atmosphere
  - Vegetation alters surface properties such as roughness, albedo, soil aggregation and macroporosity

- Topography also modulates the partitioning of water and energy fluxes at the land atmosphere boundary.
  - Slope and aspect influence energy and water balance through the local incidence angle and soil moisture redistribution
  - Spatial organization of plants is correlated with topography, plants in-turn dynamically modulate mass and heat fluxes
The simulated Above-ground Net Primary Productivity (ANPP) of C4 grass as a function of the yearly surface shortwave irradiance. The three curves correspond to slopes of different orientation: facing north (left), facing east-west (middle), and facing south (right), respectively. The point at the top of the curve corresponds to a flat element not affected by lateral effects such as radiative shading, moisture transfer in the vadose or runon.
Research Questions

1. Can a land surface model that explicitly accounts for distributed topography, hydrology, and land surface processes accurately resolve vegetation dynamics and hydrologic climate signatures?

2. What are the impacts of representing the regional scale feedbacks between the regional atmosphere and dynamic vegetation (modulated by topography) on the hydrologic states in a catchment and their effects on extreme climatic scenarios such as droughts?
Distributed Eco-hydrology Model: tRIBS

tRIBS: TIN-based Real-time Integrated Basin Simulator
VEGGIE: VEGetation Generator for Interactive Evolution
tRIBS+VEGGIE: Coupled energy, water balance; vegetation dynamics. tRIBS hereafter
Regional Atmospheric Model: WRF

- Weather Research & Forecasting Model
- Advanced meso-scale numerical weather prediction model
- Developed under AFWA stewardship, currently operational at AFWA, NCAR
- Designed to serve operational forecasting as well as atmospheric research needs
- Multiple dynamical cores (ARW, NMM), 3-dimensional variational data assimilation system, computational parallelism and system extensibility
Coupled Model: Framework

- Computationally efficient representation of topography
- tRIBS multiple watershed mode (ArcGIS modules for DEM to TIN)
- Distributed memory parallel implementation
- Model restart capability

Coupling via a “buffer” which communicates instantaneous values of atmospheric forcing and land surface boundary state variables, heat and moisture fluxes between models; allows models to implement independent parallelization schemes.

tRIBS breaks a large watershed into reaches distributed over computational nodes.

Multiple watersheds were implemented in a parallel computing framework for discretizing WRF domain into several watersheds.
Simulation Domain: Adaptive Spatial Resolution via TINs

Elevation, watersheds and channel network for the ~ 300 x 300 km coupled model simulation domain.
tRIBS Offline Validation: Energy Balance

Ground, Sensible and Latent heat flux measurements at the Kendall site starting on 5th March, 2004, 12 am and tRIBS estimates for the same period
tRIBS Offline Validation: Vegetation Dynamics
Coupled Model: Benchmarking with NOAH

- 150 x 90 km domain, centered on Tombstone, AZ
- Simulation period – Jan 01, 2000 to Jan 31, 2000
- Very Little observed precipitation in the simulation period
- Comparison of WRF-tRIBS with WRF-NOAH as sanity checks
- Boundary and Initial Conditions: GFS dss083.2

Skin and Air Temperatures

Energy Fluxes

[Graphs showing skin temperature, air temperature, and energy fluxes for Sensible, Latent, and Ground.]

Domain Averaged
Coupled Model: **Large Domain Simulations**

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<tr>
<th>Physics parameterization</th>
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<td>Time step, dX</td>
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<td>Cumulus Option</td>
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<td>Longwave Option</td>
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<td>Microphysics Option</td>
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LBC’s are obtained from NARR-A
Coupled Model: Energy Partition (tRIBS)

Energy partition (2002-08-01:09:00) estimated by tRIBs (upscaled to 2km and passed to WRF)
Coupled Model: Energy Partition (WRF)

2002_08_02:00
Coupled Model: Accumulated Precipitation
Comparison With Sounder Profile

Sounding data from MADIS: KSUS station

8/1/2002:00
(Model initialization)
Comparison With Sounder Profile

Sounding data from
MADIS: KSUS station

8/2/2002:00
Comparison With Sounder Profile

Sounding data from MADIS: KSUS station

8/4/2002:00
Conclusions

- The tRIBS model performed well in simulating the energy balance as well as vegetation dynamics at the Kendall site
  - TBD: Spatially distributed vegetation dynamics, multiple plant functional types

- Short term coupled model simulations compare well with NOAH and available atmospheric sounding observations
  - TBD: Long term integrations for multiple cases of vegetation (static, dynamic) and topography (flat, observed)

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