Integrating Remote Sensing Data on Evapotranspiration and Leaf Area Index with Hydrological Modeling:

Impacts on Model Performance in the Connecticut River Basin

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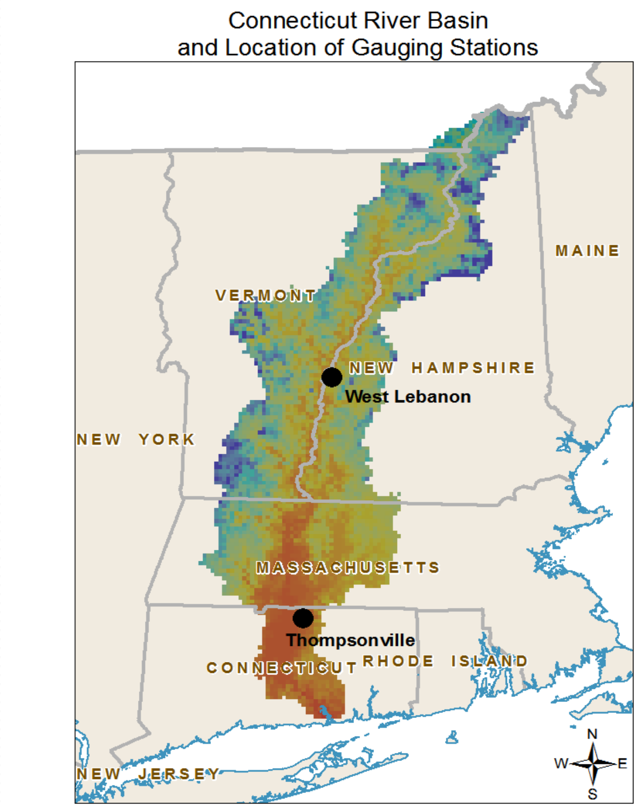
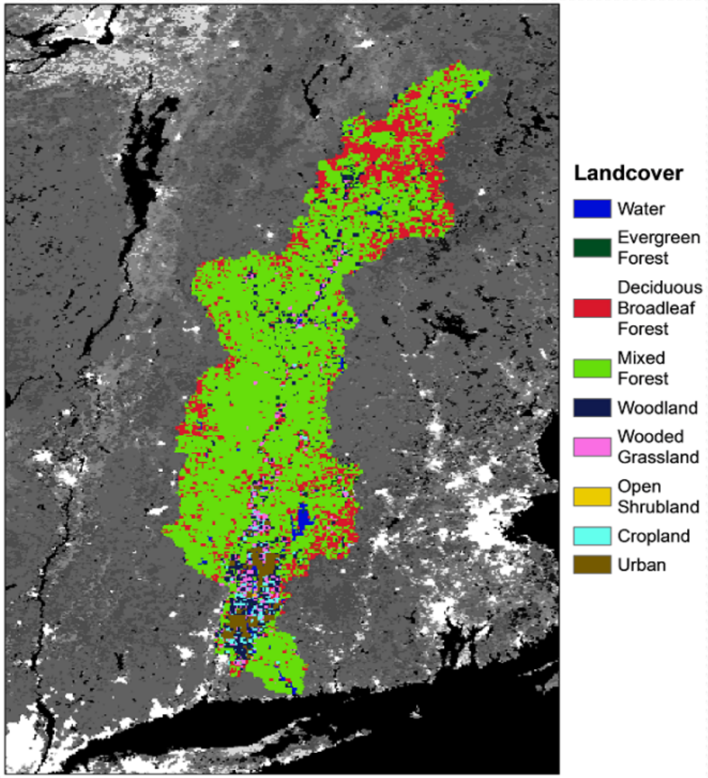
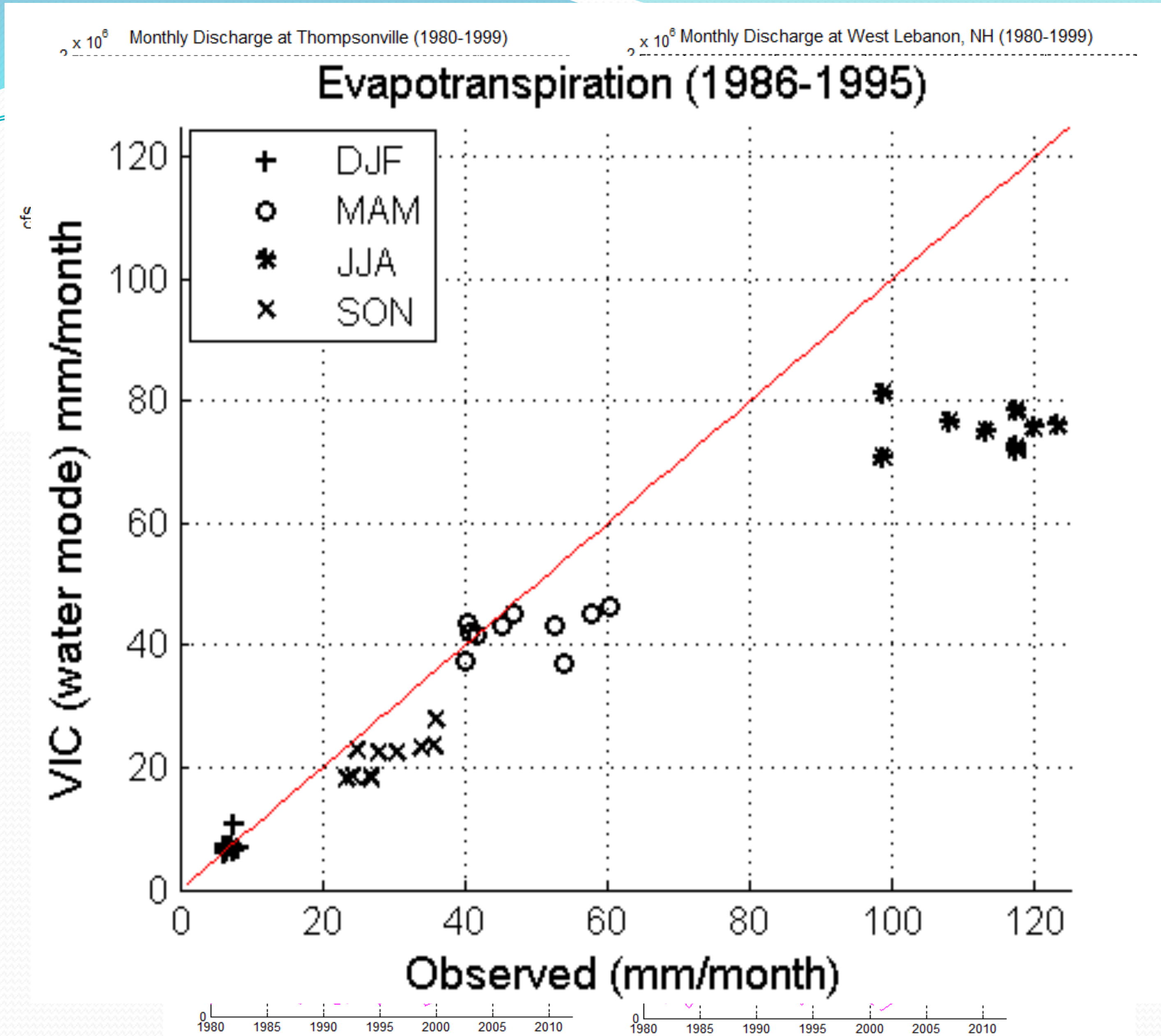
Connecticut River Basin





- The Connecticut River Basin is situated in the states of Connecticut, Massachusetts, Vermont, and New Hampshire
- Discharges into Long Island Sound near Old Saybrook, Ct
- The watershed consists of 79% forests and 11% agricultural
- It provides 70% of the fresh water which enters Long Island Sound and has a drainage basin of approximately 11,000 square miles

- Accurate parameterization of evapotranspiration processes in land surface and hydrological models is important to realistic simulation of the state of land surface and river flow.
- Many previous studies have documented a general underestimation of ET (particularly in summer months) and overestimation of runoff ratio in the VIC model (Xia et al. 2012, Vano et al. 2012, Sheffield et al. 2012)
- According to Xia et al. (2014), among the NLDAS-2 models, VIC-simulated ET is the lowest, and is less than observation for most of the year and particularly in the summer.
- Our modeling results for the Connecticut River Basin (CRB) using VIC driven with the NLDAS-2 forcing data (Parr & Wang, 2014) are consistent with the general behavior/biases of VIC found in previous studies.

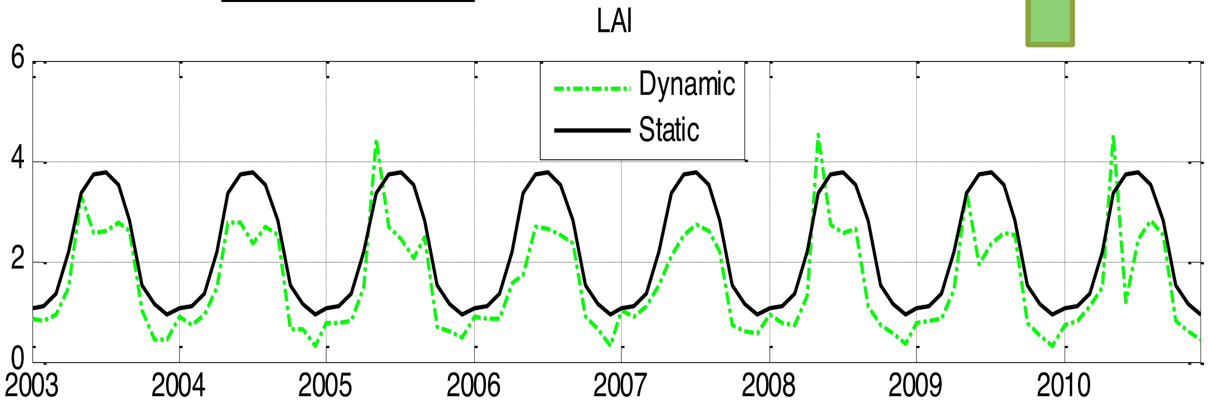

x 10^6 Monthly Discharge at Thompsonville (1980-1999)
x 10^6 Monthly Discharge at West Lebanon, NH (1980-1999)
Evapotranspiration (1986-1995)
DJF
MAM
JJA
SON
VIC (water mode) mm/month
Observed (mm/month)
0
20
40
60
80
100
120
1980
1985
1990
1995
2000
2005
2010

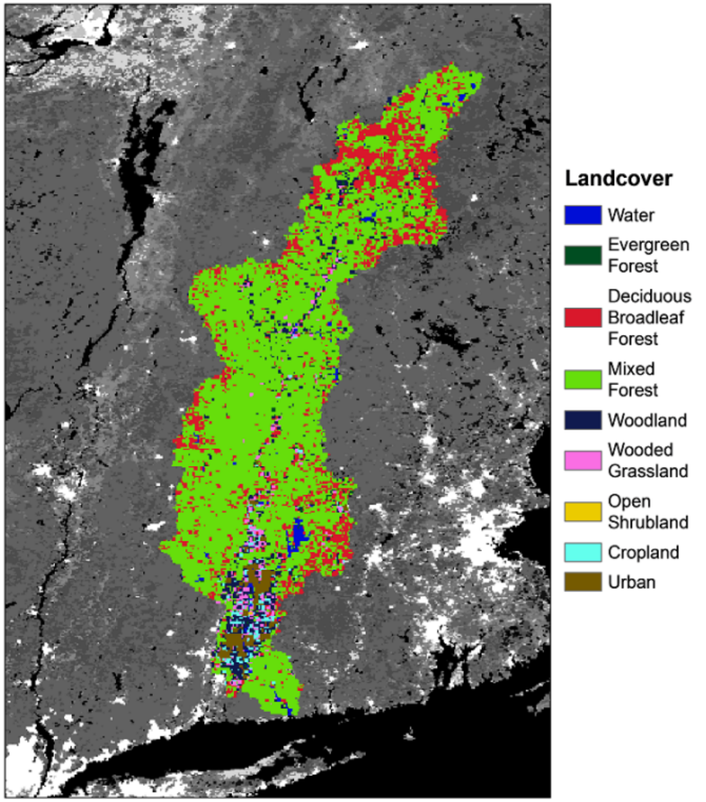
- Kite and Droogers (2000) used eight different methods of estimating actual evaporation and transpiration. They found a wide range of ET estimate from the various methods, and no method is evidently better than others.
- Weiß, M & Menzel 2008: Compared four different potential evapotranspiration equations to assess their impact on the simulated stream flow, and found significant differences among the four equations.
- In the absence of improved prameterization of ET, we address this modeling challenge through incorporating satellite remote sensing data for evapotranspiration (**ET**) and vegetation (**LAI**) into **VIC**.

"VICVEG"

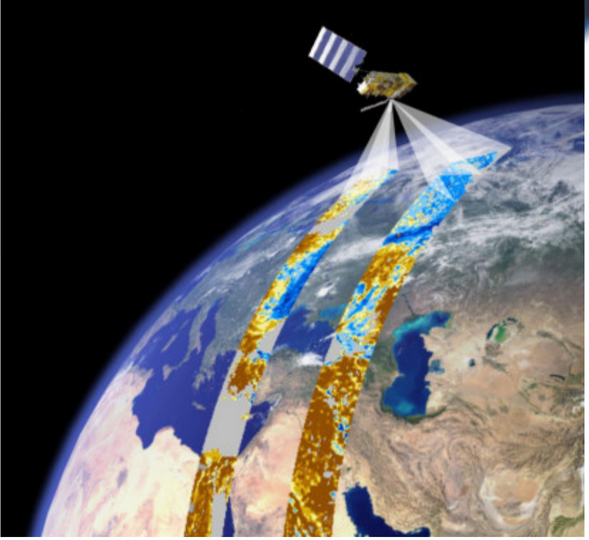
- **<u>Leaf Area Index (LAI)</u>**
- 8-day resolution; 2003-2011
- MODIS sensors - Terra and Aqua satellites
- A monthly average is derived for a 1km spatial resolution matching the land cover data set

The MODIS LAI includes not only <u>monthly</u> but also **<u>inter-annual</u>** variations





Within the model, LAI quantifies canopy cover and influences the maximum amount of water intercepted by the canopy, canopy resistance for transpiration and root water uptake and therefore evapotranspiration rates



"VICET" model: Making use of ET Data Derived from Remote Sensing

- Monthly ET data from NASA JPL (Fisher et al., 2008)
- 1986-1995; 0.5-degree spatial resolution
- Surface Radiation Budget Algorithm
- Rn, T_a and *e* taken from the ISLSCP-II
- Visible spectrum reflectance & near-infrared spectrum reflectance gathered with AVHRR

“VICET” Methodology

VIC calculates each ET component (canopy evaporation, transpiration, bare ground evaporation, canopy sublimation, and surface sublimation) separately at daily (water-only mode) or hourly (full mode) time step, while the ET data is monthly.

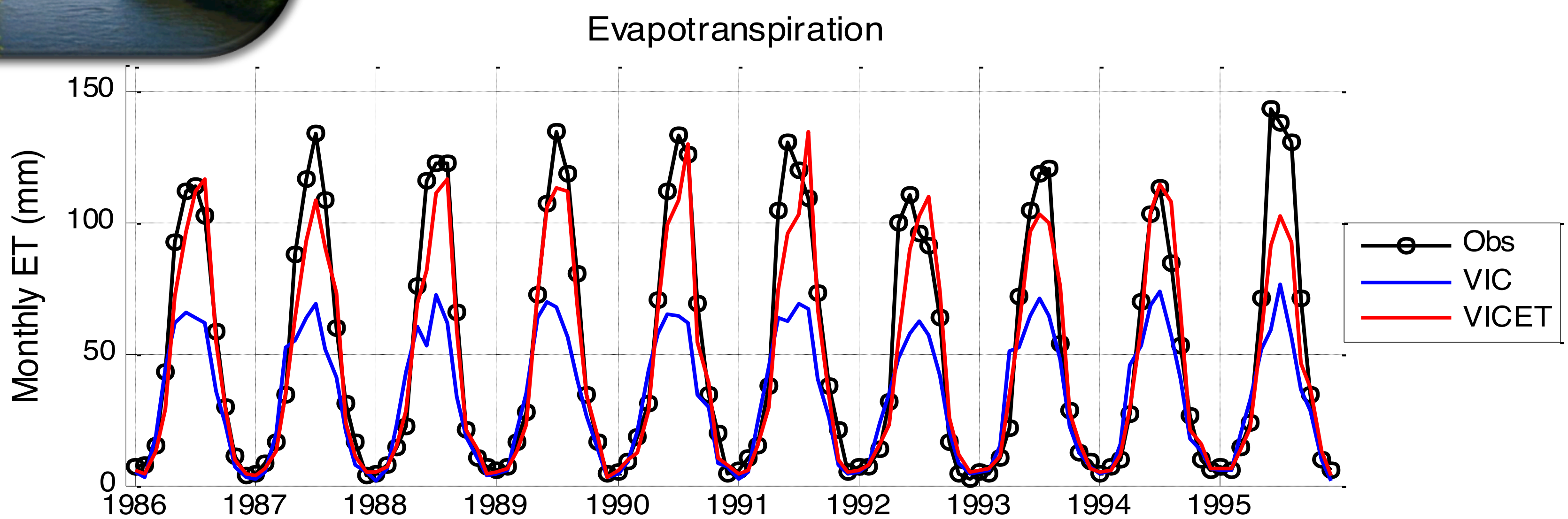
Step 1: Run the default VIC model over the ET data period (1986-1995) and over any given period of interest

Step 2: Develop a relationship between monthly average of VIC-simulated ET and observed monthly ET data during the period 1986-1995 (e.g., simple scaling ratio, linear regression, quantile mapping) (linear regression is used here)

Step 3: Use this monthly relationship to convert the VIC-simulated ET in the given period of interest to a “corrected” ET, with the partitioning ratio among the five components as well as their temporal (hourly or daily) variation following the default VIC results

Step 4: Run the modified VIC (“VICET”) for the given period to replace each of the five ET components simulated by the model with the “corrected” ET components

This approach uses the ET data as a meteorological forcing for soil moisture and runoff. The runoff and soil moisture from the “VICET” run is therefore expected to be more accurate than results from the default VIC run.

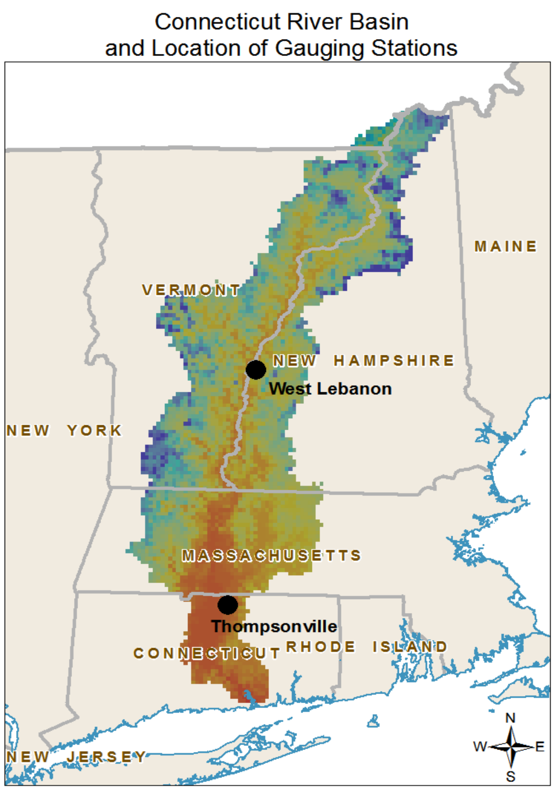


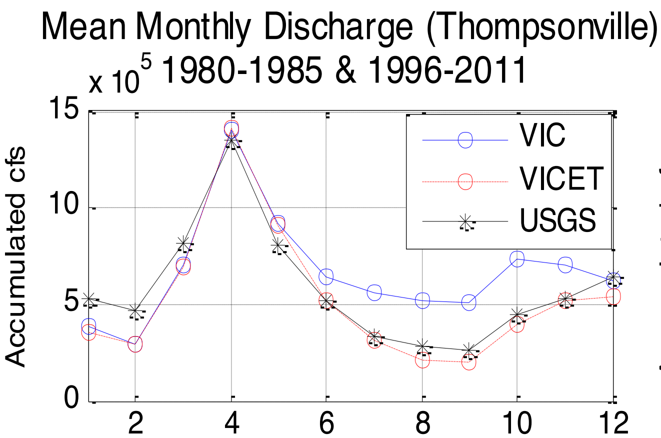
Difference between Obs and VICET: Mass conservation check within the model (for each time step) leading to reiteration within the model to adjust physically unrealistic values:

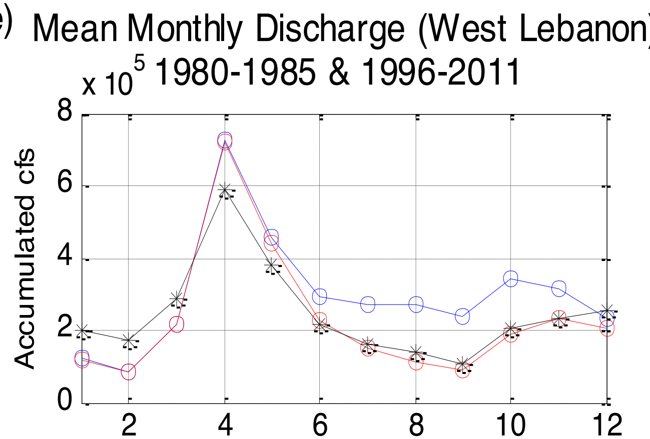
→ if canopy evaporation amount is greater than the current storage of the canopy, it will be reduced back to the value of the canopy storage.

→ ground evaporation cannot exceed what is currently stored at the surface

→ transpiration will not deplete soil moisture past the wilting point

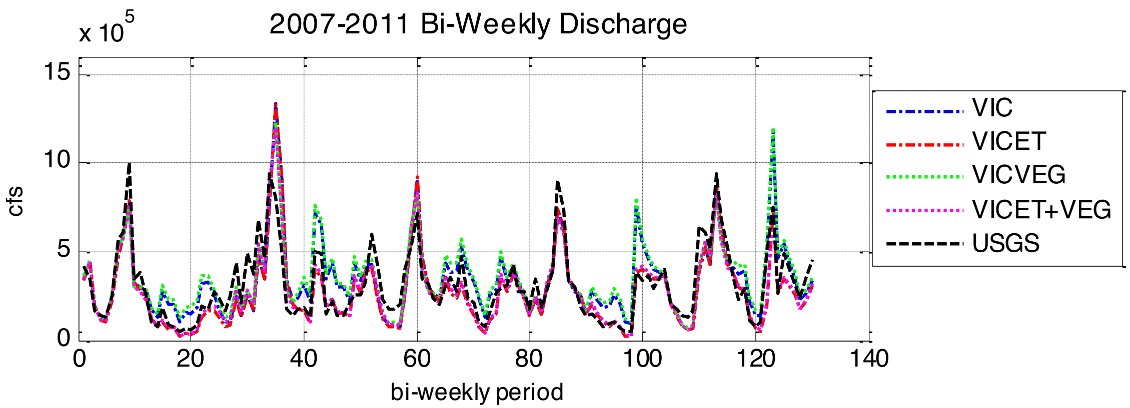


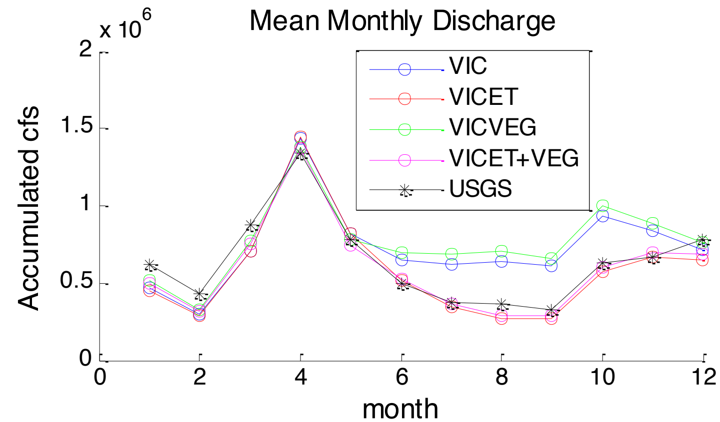


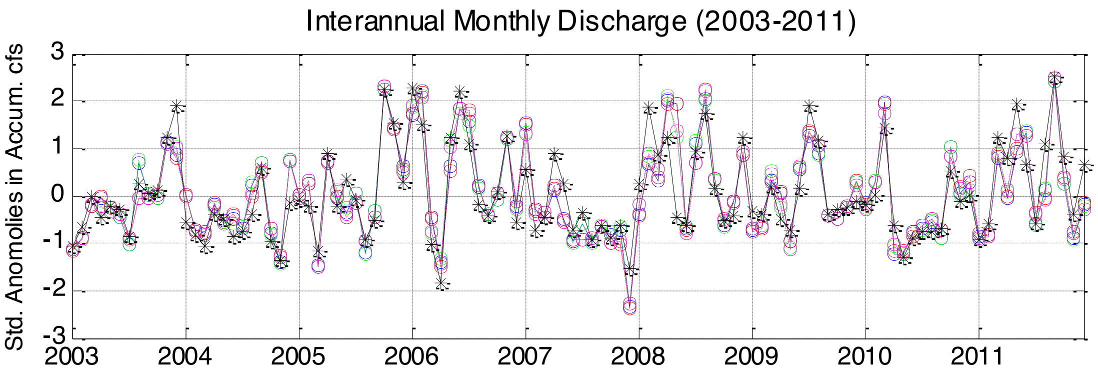


Stream flow Comparison 1980-1985 & 1996-2011
(for period without observational ET data)

	Correlation (r)		RMSE (1000 cfs)	
	VIC	VICET	VIC	VICET
Daily	0.7538	**0.8091**	12.12	10.6
Bi-weekly	0.8504	**0.9052**	119.1	**94.5**
Monthly	0.8495	**0.9759**	175.3	**95.7**







Bi-weekly Correlations for 2003-2011 (LAI data availability)

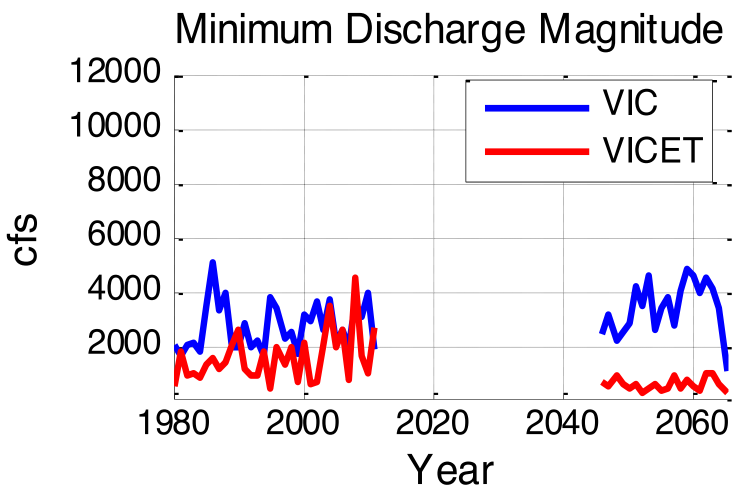
VIC:	0.808
VICET:	**0.878**
VICVEG:	0.812
VICCombination:	**0.910**

Stream Flow Comparison (2003-2011)

		Correlation (r)			
Time scale	Station	VIC	VICET	VICVEG	VICET+VEG
Daily	Thomps.	0.729	**0.795**	0.727	**0.811**
	W. Lebn.	0.709	**0.763**	0.702	**0.772**
Bi-weekly	Thomps.	0.808	**0.8783**	0.8123	**0.910**
	W. Lebn.	0.796	**0.855**	0.795	**0.876**
Monthly (seasonal)	Thomps.	0.798	**0.969**	0.759	**0.982**
	W. Lebn.	0.820	**0.968**	0.782	**0.975**
		RMSE (1000 cfs)			
Time scale	.Station	VIC	VICET	VICVEG	VICET+VEG
Daily	Thomps	12.7	10.7	13.0	**10**
	W. Lebn.	6.5	5.5	6.7	**5.3**
Bi-weekly	Thomps.	134	109	135	**91**
	W. Lebn.	74	61	73	**53**
Monthly (seasonal)	Thomps.	193	101	220	**72**
	W. Lebn.	104	60	113	**46**

Experiments on Future Projections Driven with Spatially Downscaled and Bias-Corrected NARCCAP Model Output

- Peak timing and magnitude show no observable change in signal between simulation types
- However, minimum discharge (as well as 5-day minimum discharge) projections are qualitatively different

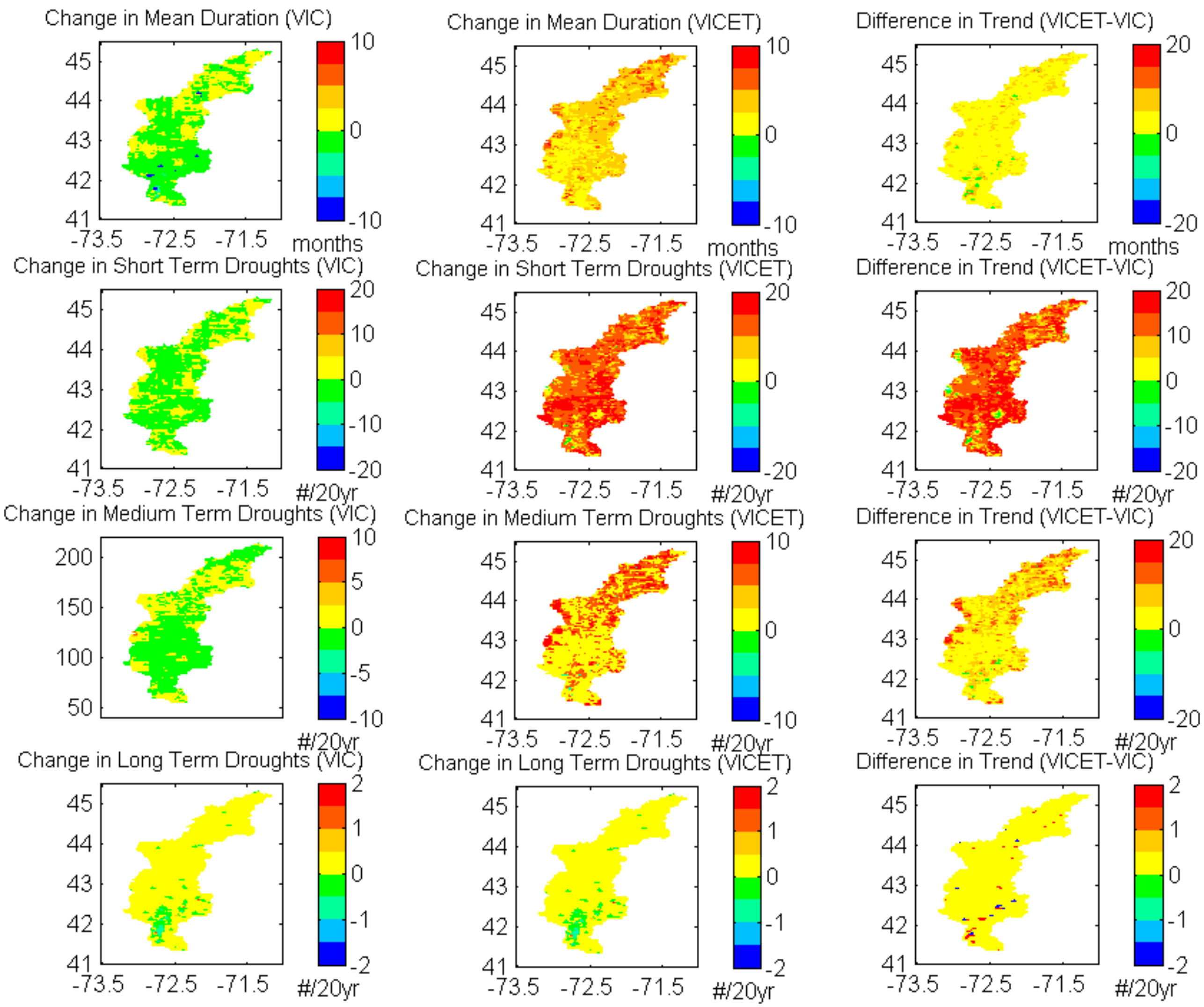


Means (cfs):

VIC 2,734 → 3,443
increasing by 12 cfs/year

VICET: 1,592 → 607.21
decreasing by 13 cfs/year

Also takes place at a later date in the year by 22 days (end of Sept. /early Oct. rather than beginning of Sept.)



This analysis method was adapted from a similar one conducted by Sheffield & Wood (2007) where the percentile was based on monthly rather than daily data

(4-6 months)

(7-11 months)

(≥12 months)

- The incorporation of the remotely sensed ET data into VIC leads to significant model improvements towards river flow estimation
- The VICET+VEG combination model shows the greatest improvements on all time scales examined (the seasonal, bi-weekly, and daily scales)
- Similar techniques can be applied to other models and/or other regions (e.g., over the NLDAS domain) to improve the model performance.
- Ideally validation of the methodology should be based on model-data comparison of both the soil moisture and river flow. Due to the lack of soil moisture data in the Connecticut River Basin, the validation here is done based on river flow measurement only.

(Hopefully, SMAP will help – possible proposal to NASA)

Results presented here are documented in a manuscript submitted to Journal of Hydrometeorology:

Parr DT, Wang GL, Bjerklie D, 2015: Integrating Remote Sensing Data on Evapotranspiration and Leaf Area Index with Hydrological Modeling: Impacts on Model Performance and Future Predictions. *Journal of Hydrometeorology*, submitted