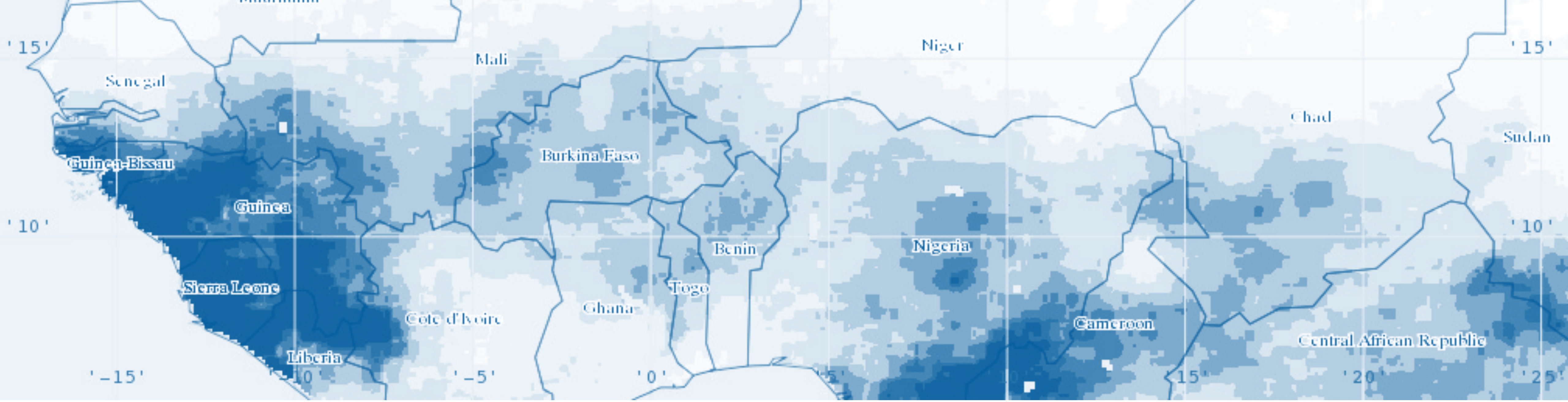


VIC CALIBRATION FOR HYDROLOGICAL EXTREME MONITORING

Kel Markert
NASA-SERVIR Mekong Regional Associate
University of Alabama in Huntsville | Earth System Science Center

8 March 2017

VIC/BCSPP Training
Huntsville, AL

OUTLINE

- VIC Variables to calibrate
- Calibration methods
  - Land surface model calibration
- Calibration best practices
- Nyando basin model calibration
- Calibration discussions

VARIABLES TO CALIBRATE

- Five typical variables to calibrate for VIC
- Other variables can be calibrated
  - Snow partitioning, Energy balance terms, Land surface parameterization
- Typical calibration is mostly focused on soil variables (movement of water through soils)

Variable	units	Description	Typical Range
Ds	%	Fraction of Ds_{max} where non-linear baseflow occurs	>0 -1
Ds_{max}	$mm \cdot day^{-1}$	Maximum baseflow that can occur from the lowest soil layer	>0 - ~30
Ws	%	Fraction of maximum soil moisture where non-linear baseflow occurs	>0 - 1
b_{inf}	n/a	Shape parameter of the VIC curve	>0 – 0.4
Soil depths (for each layer)	m	Soil depth in meters for each soil layer	0.1 – 1.5

VARIBLE CALIBRATION EFFECTS

- With a higher value of Ds, the baseflow will be higher at lower water content in lowest soil layer
- A higher value of Ws will raise the water content required for rapidly increasing, non-linear baseflow, which will tend to delay runoff peaks
- A higher value of b_{inf} gives lower infiltration and yields higher surface runoff
- Soil depth effects many model variables
  - For runoff considerations, thicker soil depths slow down (baseflow dominated) seasonal peak flows and increase the loss due to evapotranspiration

CALIBRATION METHODS

- A focus of research is on more effective parameterization and calibration methods for hydrologic models

- Manual calibrations
  - Very time consuming
  - May not provide the best parameters
  - Based on regional knowledge
- Computer calibrations
  - Computationally intensive
  - Time consuming (no user involvement)
  - Very complex
  - Provides well calibrated parameters (depending on algorithm used)

CALIBRATION METHODS

- Brute force calibrations

- Random autostart complex
  - Initialization based on random combination of parameters
  - Uses best combination of parameters to start the simplex minimization algorithm to optimize

- Genetic optimization
  - Based on the laws of natural selections
  - Initializes with random set of parameters and randomly chooses “parent” sets based on performance
  - Combines “parent” parameters to create “children”
  - Iterates for n number of generations

CALIBRATION METHODS

- Multi-Objective Complex Evolution (MOCOM-UA)
  - Developed to **calibrate models efficiently on multiple evaluation functions**
  - Larger optimization populations produce a more complete picture of the Pareto set but also increase the number of simulations

- Shuffled Complex Evolution (SCE-UA)
  - Most commonly used calibration algorithm for hydrologic applications
  - **Designed to find the global optima**
  - Starts several chains/complexes that evolve individually then shuffles parameters to make new complexes

CALIBRATING NYANDO BASIN

- We are going to perform a calibration on the Nyando basin model

- Update the global parameter simulation time for 2005-2009
- Navigate to the scripts folder in terminal
- Run the command: `$ python calibrate_vic.py 15`
  - This executes a random parameter set estimation calibration for 15 iterations

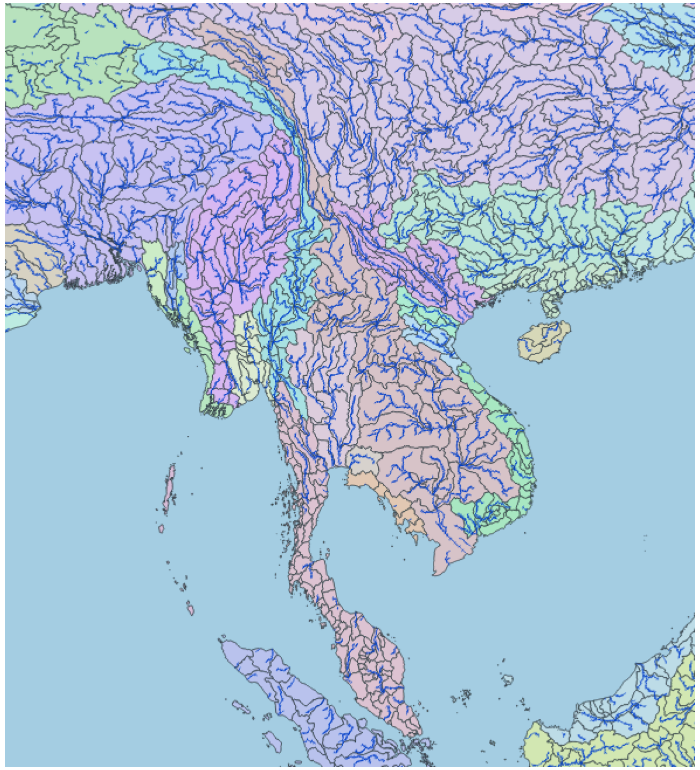
```
kmarkert@ubuntu: /media/psf/Home/Documents/servir-vic-training/scripts
kmarkert@ubuntu:/media/psf/Home/Documents/servir-vic-training/scripts$ python ca
librate_vic.py 15
Iteration 1 of 15
Iteration 2 of 15
Iteration 3 of 15
Iteration 4 of 15
Iteration 5 of 15
Iteration 6 of 15
Iteration 7 of 15
Iteration 8 of 15
Iteration 9 of 15
Iteration 10 of 15
Iteration 11 of 15
Iteration 12 of 15
Iteration 13 of 15
Iteration 14 of 15
Iteration 15 of 15
Processing time for 15 iterations: 0:27:38.878933
kmarkert@ubuntu:/media/psf/Home/Documents/servir-vic-training/scripts$
```

	A	B	C	D	E	F	G	H	I	J
1		Bias	Ds	Infilt	NSE	R	RMSE	S2Depth	S3Depth	Ws
2	0	19.1394958652	0.8890057269	0.0410198761	-0.9524018204	0.7873400514	19.5804699409	0.5849558303	1.3264989707	0.029462448
3	1	0.3909082478	0.8846596428	0.234146527	0.5619588848	0.7834956448	8.3196924421	1.165013889	0.8397157317	0.5877511305
4	2	-10.0826398119	0.224925231	0.0564933753	0.2252997494	0.8705904811	10.2574564765	1.3858243437	0.5251147441	0.8682412188
5	3	6.6811163142	0.8765031823	0.199819229	0.4728935608	0.8003549831	10.5131920183	0.4847685392	0.7217559573	0.735682563
6	4	3.4969270607	0.242767954	0.4244627549	0.5469992821	0.7697122089	8.8839665275	1.0592893299	0.692682465	0.4645152295
[illegible]	[illegible]	21.3453696927	0.6736143224	0.4980421341	-0.9878211944	0.7481202051	22.0983154971	0.3719766987	0.9777327868	0.2798206471
[illegible]	[illegible]	15.1455695202	0.4034455403	0.4771475558	-0.2091218551	0.7463172075	16.9249180645	0.6682036089	1.4780796052	0.1954846737
[illegible]	[illegible]	3.9106474169	0.5865394885	0.4788872907	0.4445600022	0.7036982335	9.7445630646	1.4731365931	0.8628163339	0.3990251202
[illegible]	[illegible]	10.279497973	0.6563373558	0.4069175728	0.1820268177	0.7313139262	13.3808221208	0.5325219206	1.3223083704	0.8505878639
[illegible]	9	4.1068022972	0.422613714	0.2289976714	0.5079492746	0.755584584	9.519351269	0.3483971051	1.0411654682	0.7118378998
[illegible]	10	4.0640710951	0.9653565851	0.4419934398	0.5870722745	0.8030917399	8.431204335	1.1290483361	0.3493707558	0.4336393677
13	11	2.1354415841	0.2220312218	0.214614984	0.645903505	0.8241435543	7.6172680012	0.6085282894	0.4567183273	0.4424581309
14	12	3.3195178374	0.8444503846	0.4683093956	0.5536350361	0.7706603767	8.6349205016	1.2975840763	0.4852601225	0.370803452
15	13	1.8007704795	0.6084476274	0.288086986	0.5935978488	0.7967974751	8.1557737904	0.9793986785	0.676613005	0.7744015252
16	14	0.0450938862	0.3224653364	0.219723789	0.6424089119	0.8347776726	7.3378755192	0.9038971372	0.4610401845	0.4381426305

- A more robust calibration script is provided (calibrate_vic_sceua.py)
  - Requires more complex set-up and interpretation of results

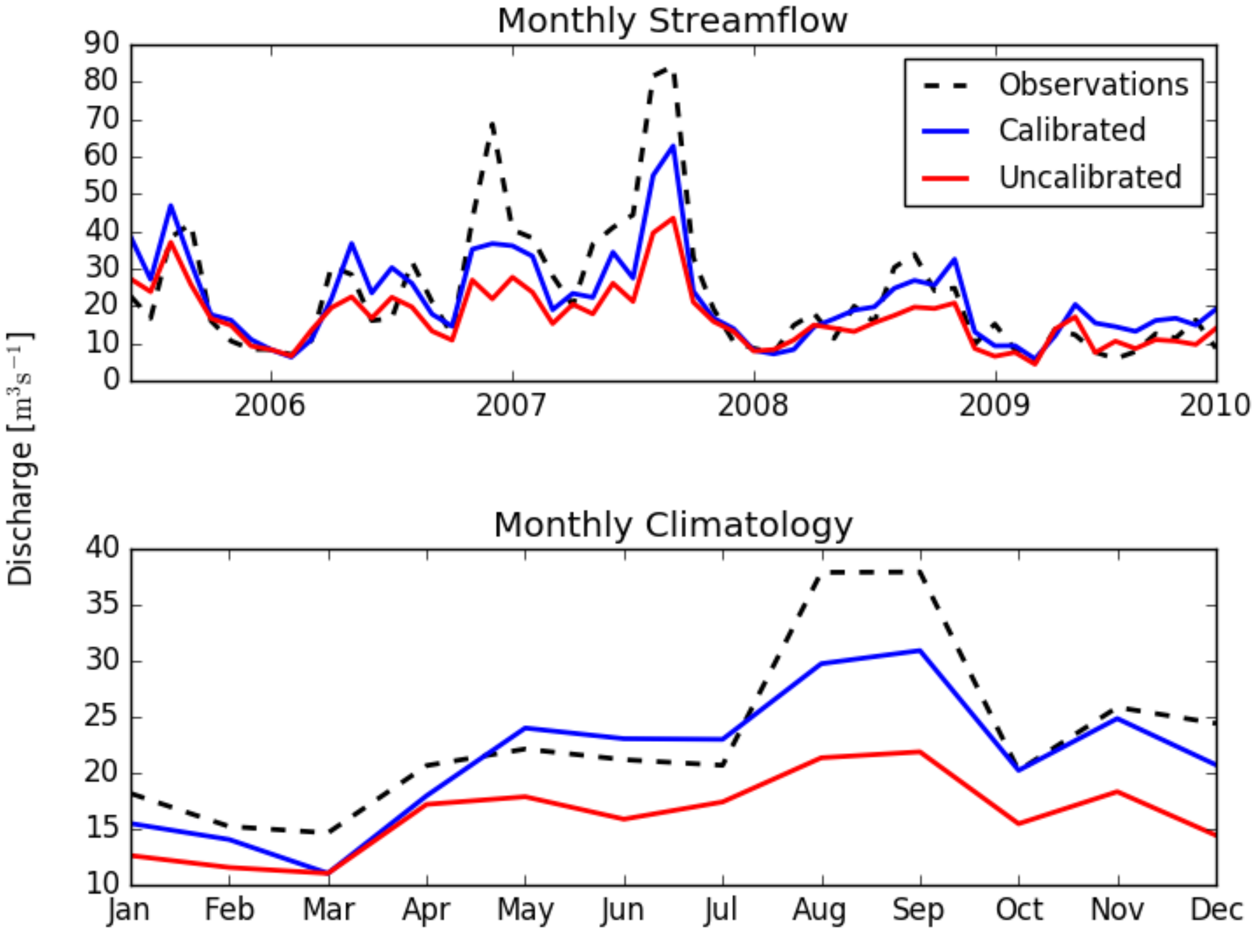
CALIBRATION BEST PRACTICES

- Necessary to have an independent record for calibration and validation (or evaluation) of the hydrologic simulation
  - Typically save approximately half of observed time series for validation
- Calibrate by sub-basin and combine for entire region
- Common observation to use for calibration is streamflow
  - Can calibrate model using other observed parameters (soil moisture, ET, snow depth)
  - In situ measurements vs satellite observations



CALIBRATION FOR NYANDO BASIN

- Used the SCE-UA algorithm
  - Parameter populations of 500 each running 55 simulations with one chain (12 hour runtime)

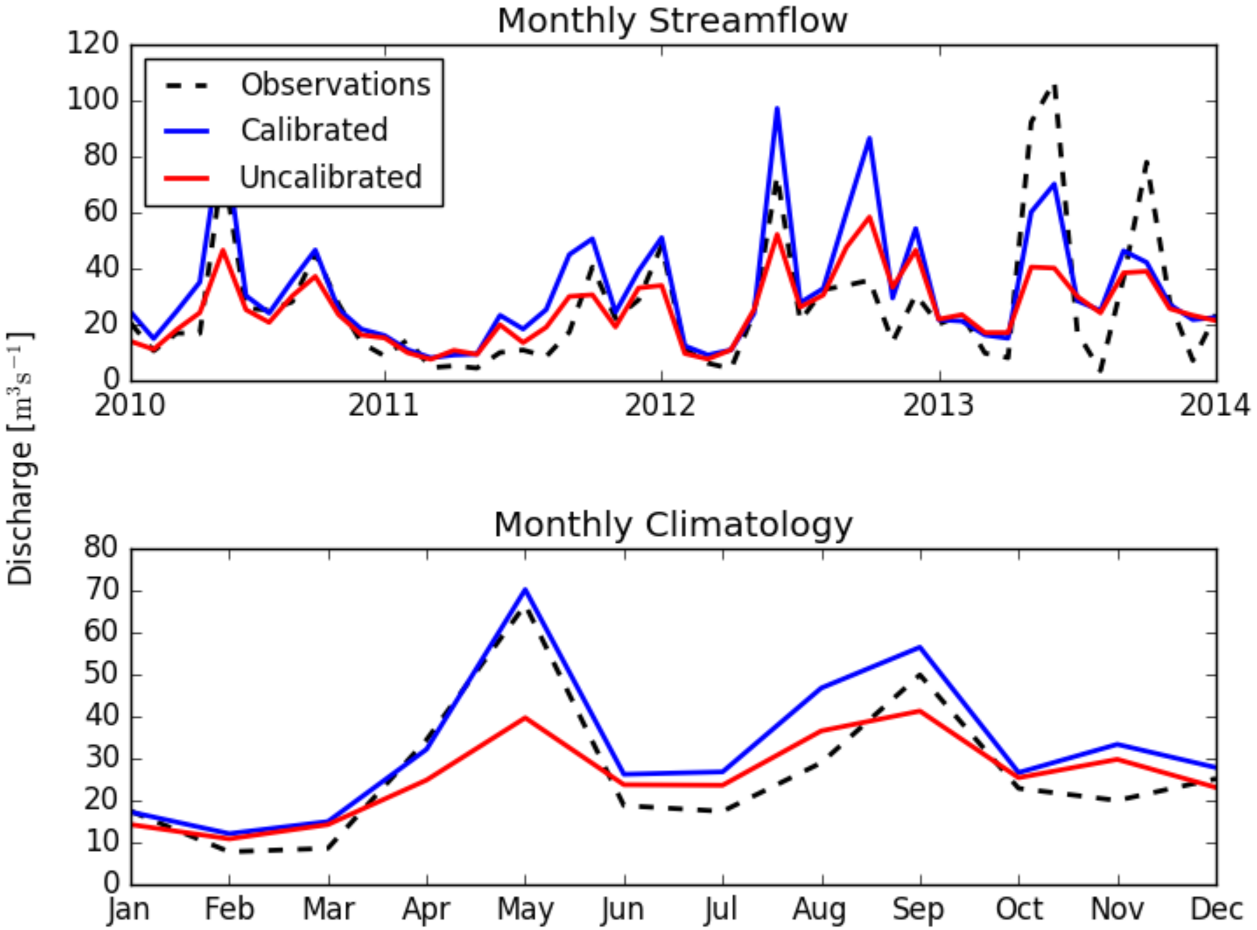


- Uncalibrated NSE: 0.42
- Calibrated NSE: 0.72
  - Bias: -1.11 $m^3 \cdot s^{-1}$
  - RMSE: 6.80 $m^3 \cdot s^{-1}$

NYANDO BASIN MODEL VALIDATION

- Model over/under estimates peak flow
  - Possible errors with input precipitation dataset

- Uncalibrated NSE: 0.48
- Calibrated NSE: 0.55
  - Bias: -6.07 $m^3 s^{-1}$
  - RMSE: 10.89 $m^3 s^{-1}$



EFFICIENT CALIBRATION TIPS

- Grid cells with vegetation classes that cover less than 1-2 % of the grid cell can be removed
  - Should not be done when evaluating changes in streamflow as a function of change in vegetation
- Only calibrate on wet pixels (grid cells that receive high precipitation and significantly contribute to streamflow)
- Calibrate model using a large grid cell (~1°) and extract parameters to smaller grid for simulations
  - Significantly decreases calibration time
- Calibrate using water balance mode

ADVANCED CALIBRATION METHODS

- Spare grid calibration
  - Randomly selected calibration grid cells
  - Spatially interpolate calibrated factors
  - Based on monthly spatially homogeneous values (runoff ratio) at the pixel level
    - No need for long-term streamflow or routing model
  - Used to calibrate the NLDAS model

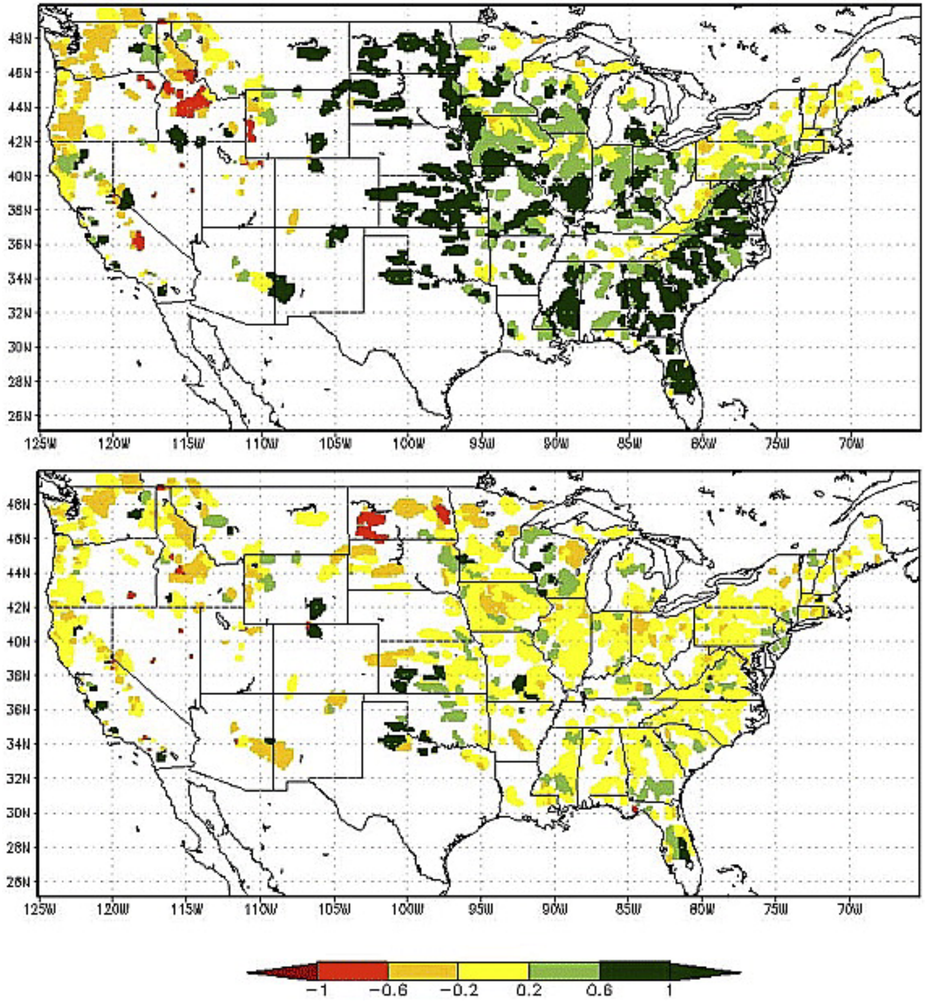
WATER RESOURCES RESEARCH, VOL. 44, W09411, doi:10.1029/2007WR006513, 2008

An efficient calibration method for continental-scale land surface modeling

Tara J. Troy,[1] Eric F. Wood,[1] and Justin Sheffield[1]

Received 11 September 2007; revised 31 March 2008; accepted 27 May 2008; published 6 September 2008.

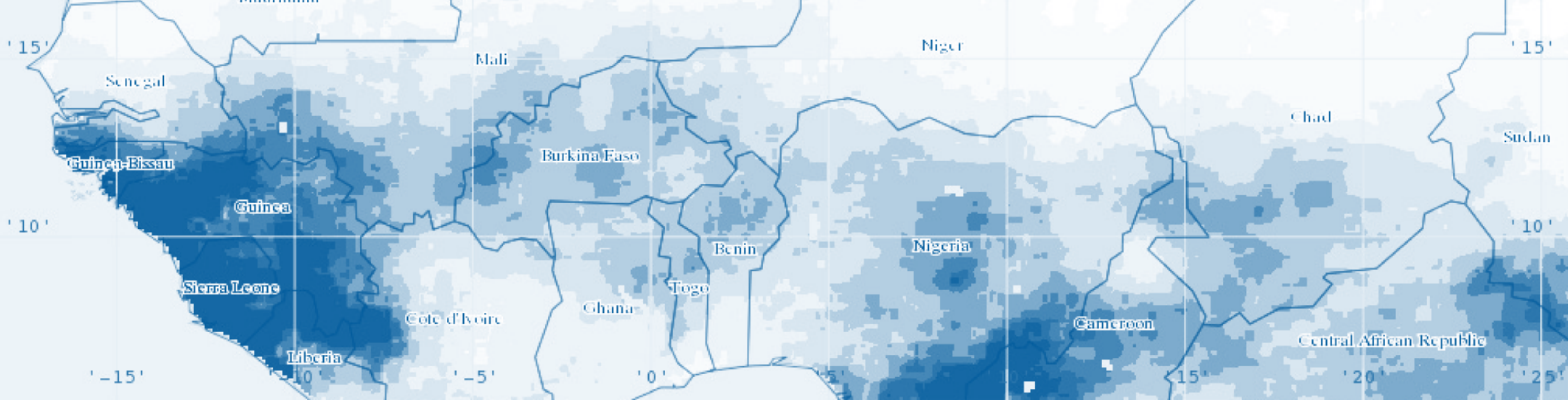
[1] Land surface models contain physically conceptualized parameters that require calibration for optimal model performance. However, calibration time can be prohibitive. To reduce computational time, we calibrated the VIC land surface model for a subset of the grid cells and then interpolated the parameters to the uncalibrated grid cells. In the continental United States, the "observation" to which we calibrated was the monthly runoff ratio, calculated for 1130 small basins throughout the country and interpolated to those grid cells that did not fall within a small gauged basin. The results demonstrated that



(Troy 2008, Open access article in Water Resources Research) Volume 44, Issue 9, W09411, 6 SEP 2008 DOI: 10.1029/2007WR006513
http://onlinelibrary.wiley.com/doi/10.1029/2007WR006513/full#wrcr11550-fig-0001

CALIBRATION CONSIDERATIONS

- Calibration methods depends on the application of the model
  - Includes data used calibrated against (e.g. streamflow forecasting model should be calibrated against observed streamflow)
  - Calibrating against observed streamflow does not necessarily mean ET or snow depth may be calibrated
- Calibration results and can be limited by input data quality
  - Calibration can only go as far as the model and data allows
- Operational models should be calibrated regularly
- Daily streamflow requires further calibration of the routing model parameters



THANK YOU

Kel Markert

kel.markert@nasa.gov

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