Derivation of Energy and Water Balance Parameters from ENVISAT AATSR Data across Volta Savannah Catchments in West Africa

By

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Quote

"The difficulty of coping with climate change impacts in Africa whose results include frequent droughts, floods, extreme temperatures, and land degradation is one of the numerous reasons why the continent (though constitutes 13% of global population) has 32 of the world's 38 extremely poor and underdeveloped countries".

Source: Washington et al. (2006) *BAMS,* Oct. 1335-1366

Climate change & Hydrology Research (West Africa)

•AGRHYMET/IRD – CATCH Sahel monitoring stations (1990 – to date) Balme et al. (2006)

•HAPEX-Sahel (1991 – 1995) Goutourbe et al. (1994); (1997); Prince et al. (1995)

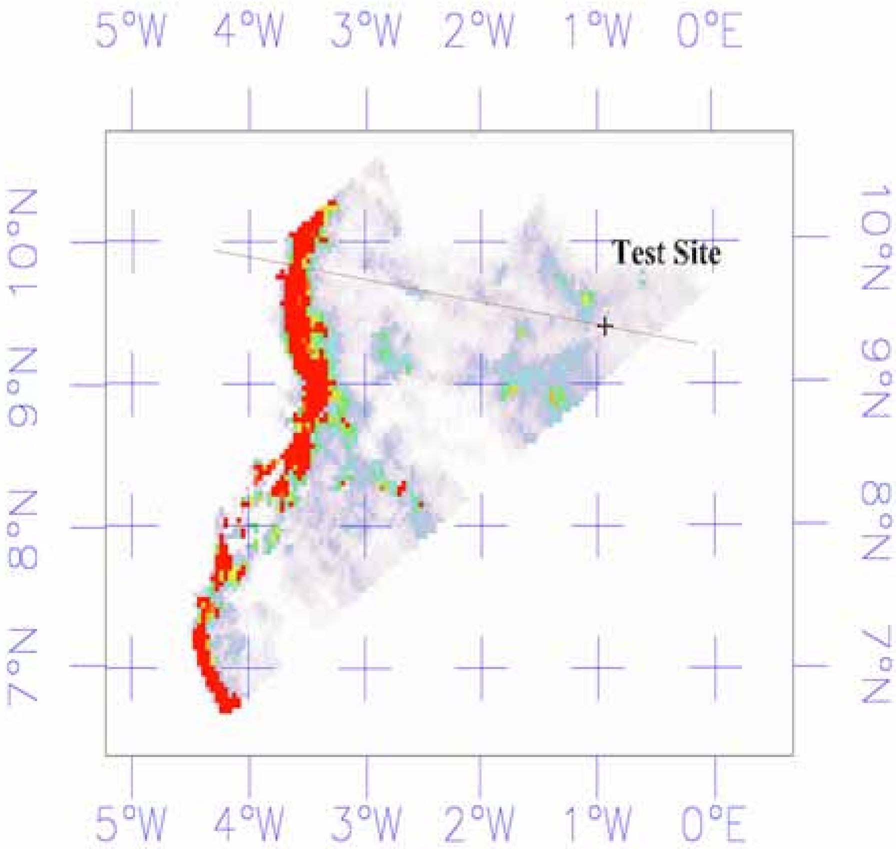
•GLOWA-Volta Experiment (1999-to date) ZEF (1999); van de Giesen et al. (2002)

•Fragmented research (institutionally-based)

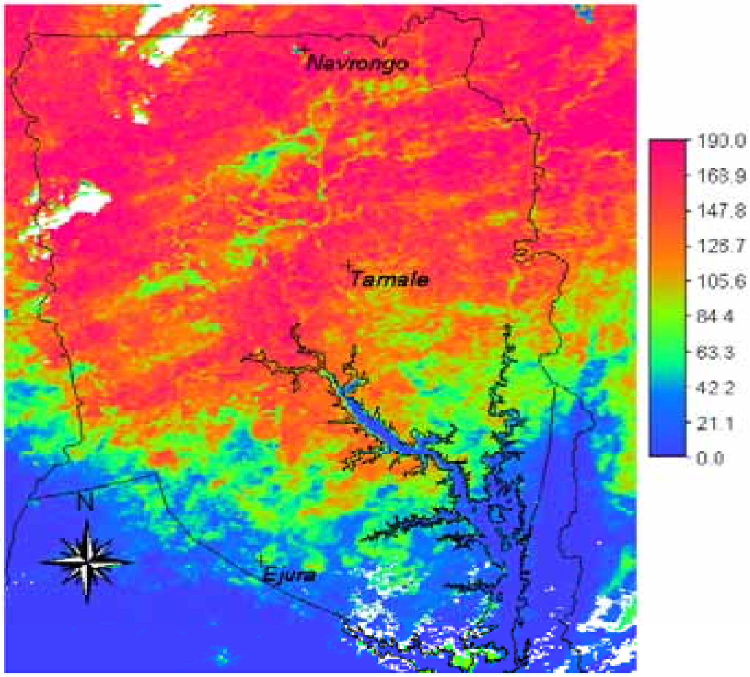
The above and several others have fully documented changes in (1) climate, (2) land-use & (3) hydrology over West Africa

Volta Remote Sensing – Hydrology (GLOWA)

(a) TRMM rainfall



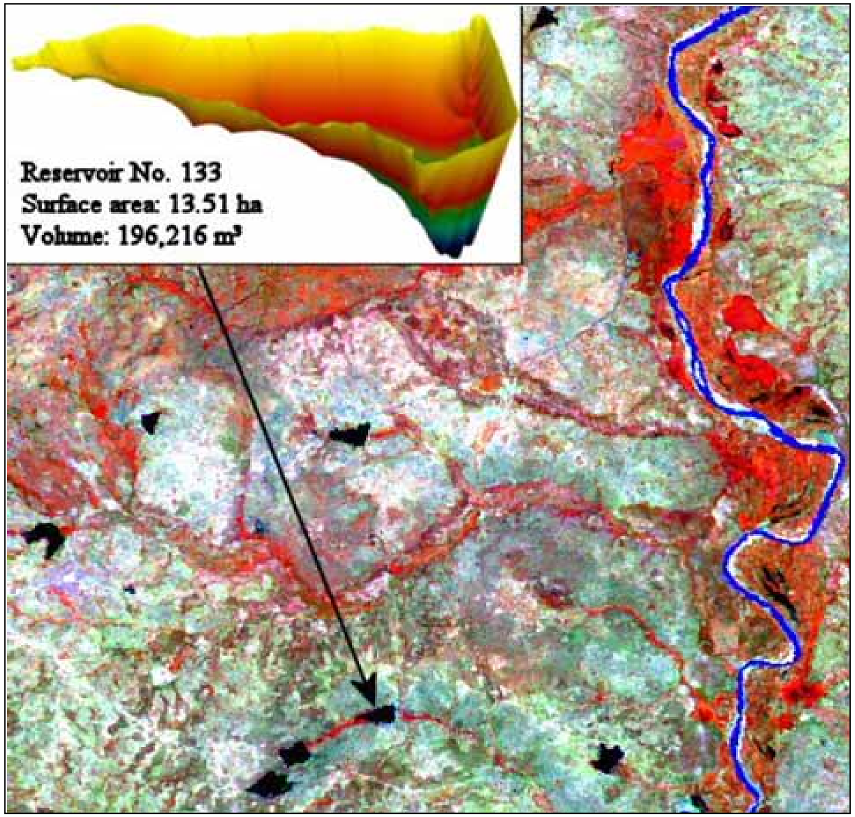
(b) Energy fluxes (Sensible heat [W m^-2])



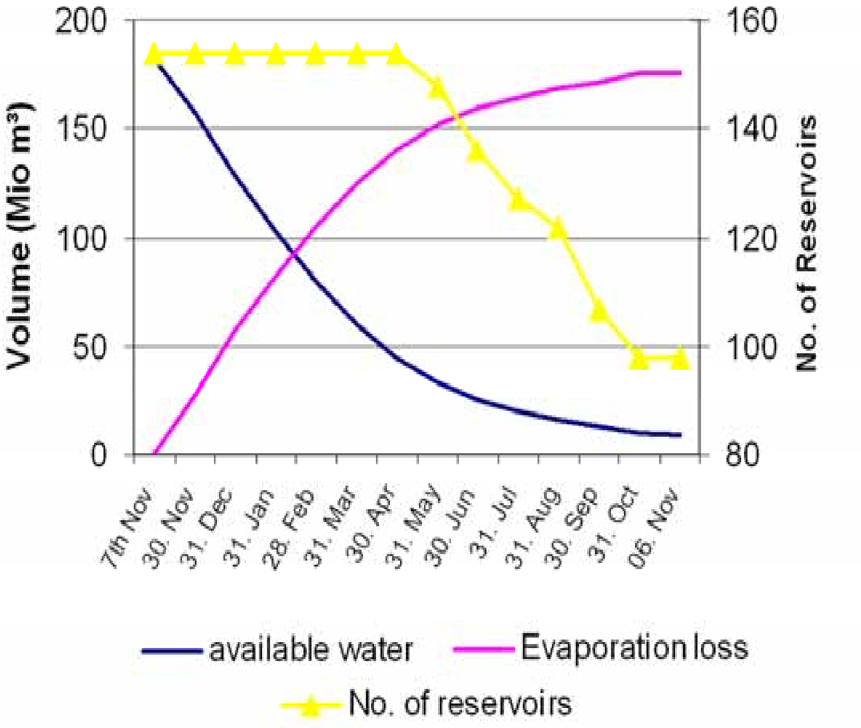
Source: Hafeez et al. (2003?)

Water Resources Monitoring – GLOWA

(a)

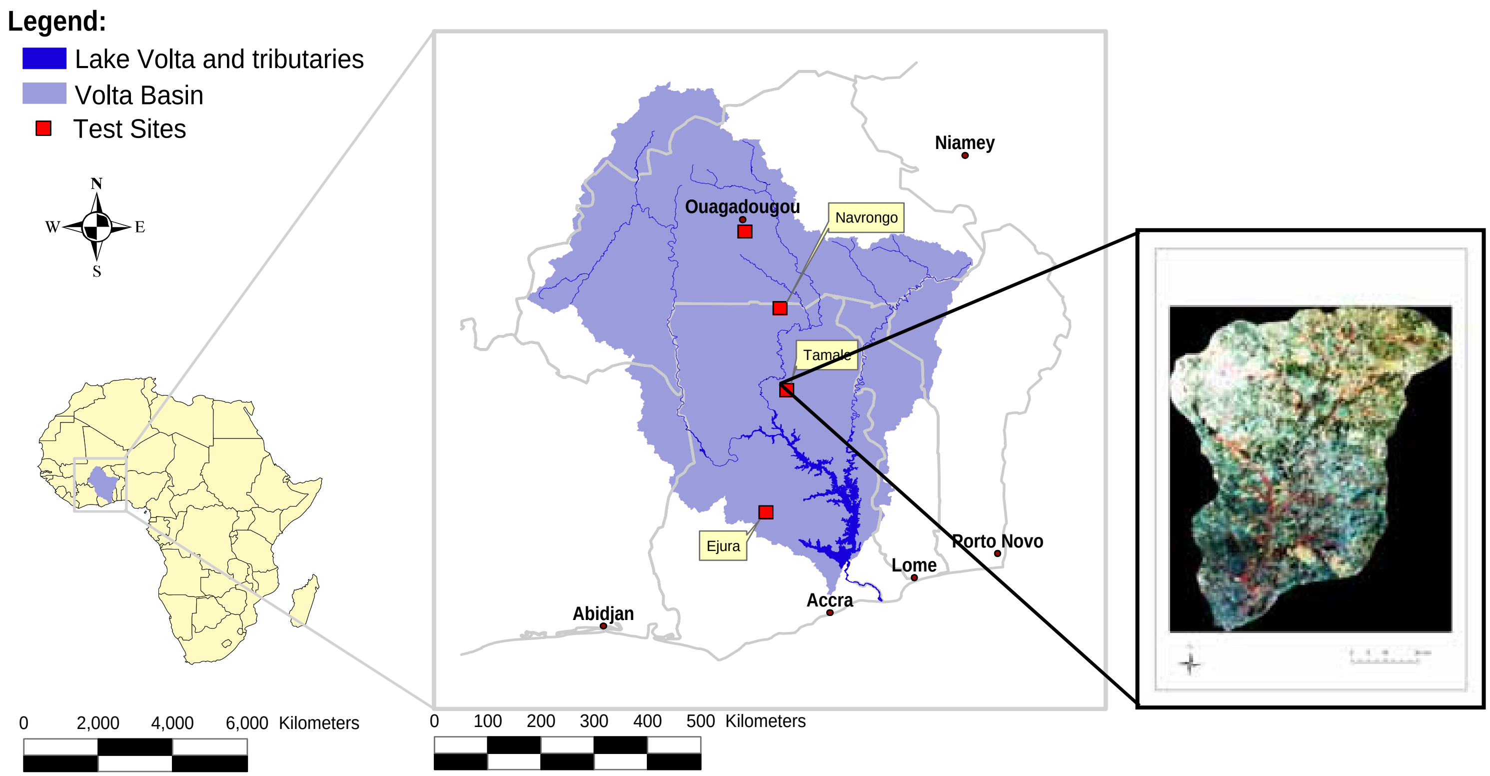


(b)



Source: Hafeez et al. (2003?)

Savannah Volta Basin



Courtesy: Modified after ZEF (1999) GLOWA-Volta

Ecosystem Responses & Drivers

(Spatial data for hydrological modelling is a critical issue)

Data: Recent Sensors of Hydrological Importance

(1) Medium resolution data

Geometrically-corrected, very high spectral signatures
MODIS - high temporal frequency
(1-2 day global coverage [36 channels])
AATSR – data from reflectance and TIR bands - corrected brightness temperatures (BT)
(No re-calibration needed, routine derivation of energy balance parameters e.g. NDVI, Ts)

(2) High resolution data

Landsat ETM+/ASTER – fully calibrated & multi-purpose
Spatial validation data
ASTER – stereoscopic capabilities for DEM

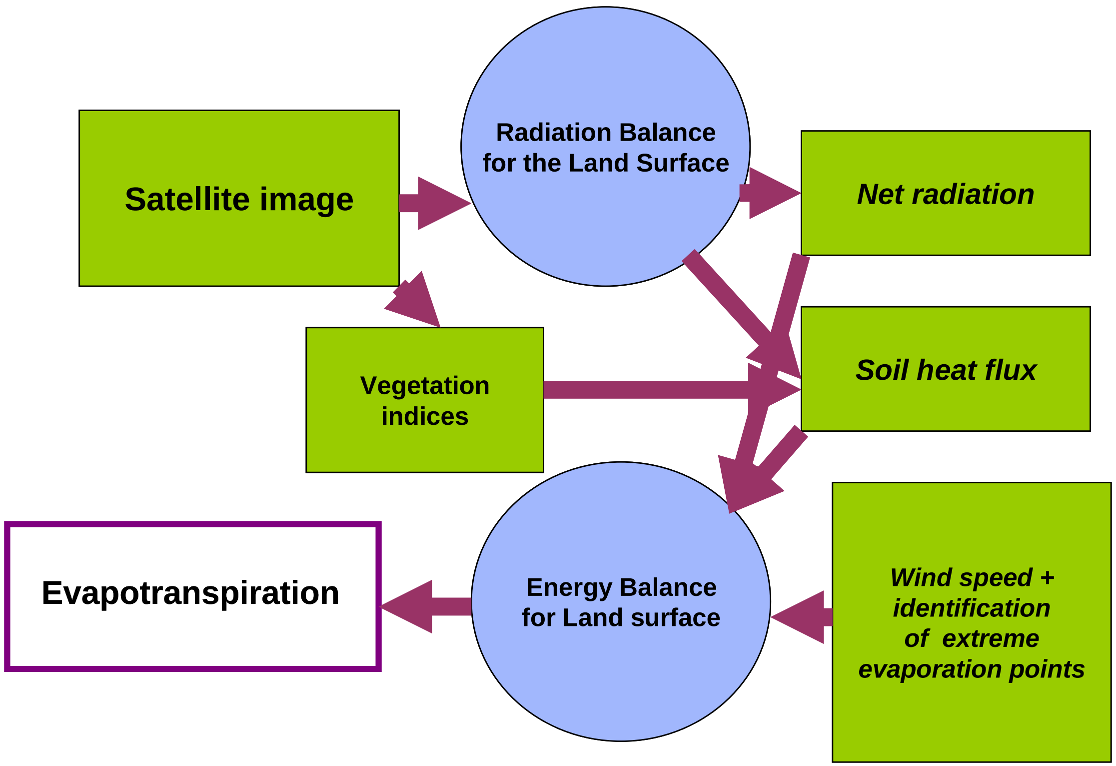
(Note: DEM over the Volta already produced from SRTM 90m data)

Key Sensor Characteristics

Data source	Spatial resolution (m)	Spectral range (µm)			
		Visible	NIR	MIR	TIR
ASTER Level 1B	**15, 30 & 90** for VIS, IR & TIR spectral ranges, respectively	B1 (0.52-0.60) **B2 (0.63-0.69)**	**B3 (0.78-0.86)**	B4 (1.60-1.70) B5 (2.14-2.18) B6 (2.18-2.22) B7 (2.23-2.28) B8 (2.29-2.36) B9 (2.36-2.4.3)	B10 (8.12-8.47) B11 (8.47-8.82) B12 (8.92-9.27) **B13 (10.2-10.8)** **B14 (10.95-11.65)**
Landsat ETM+	**30 (15m for pan** and 60m for thermal band)	B1 (0.45-0.52) B2 (0.52-0.60) **B3 (0.63-0.69)** Pan (0.5-0.90)	**B4 (0.76-0.90)**	B5 (1.55-1.75) B7 (2.08-2.35)	**B6 (10.4-12.50)**
ENVISAT AATSR Level 1B	**1km**	**B1 (0.545-0.565)** **B2 (0.649-0.669)**	**B3 (0.855-0.875)**	**Band4 (1.580-1.640)**	**B5 (3.505-3.895)** **B6 (10.40-11.30)** **B7 (11.50-12.50)**
MODIS Level 1B	**250 (500m** for bands 3-7) and **1km** for bands 8-36)	**B1 (0.620-0.670)** B3-14 (0.459-0.683)	**B2 (0.841-0.876)** B5(1.230-1.250) B15-19 (0.743-0.965)	Band6-7 (1.628-2.155) Band26 (1.36-1.39)	B20-25 (3.66-4.54) **B31 (10.78-11.28)** **B32 (11.77-12.27)**

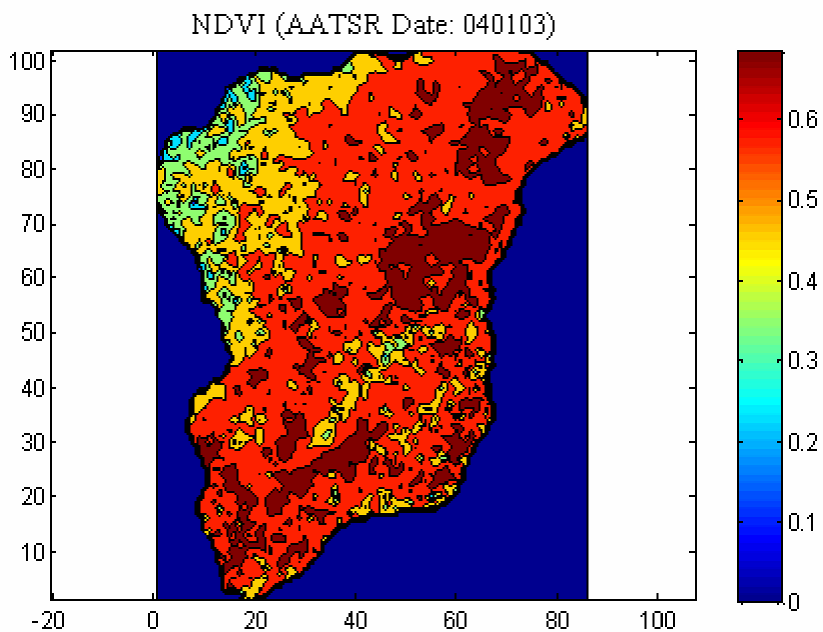
B = image band, green bands = vegetation mapping, red bands = temperature mapping

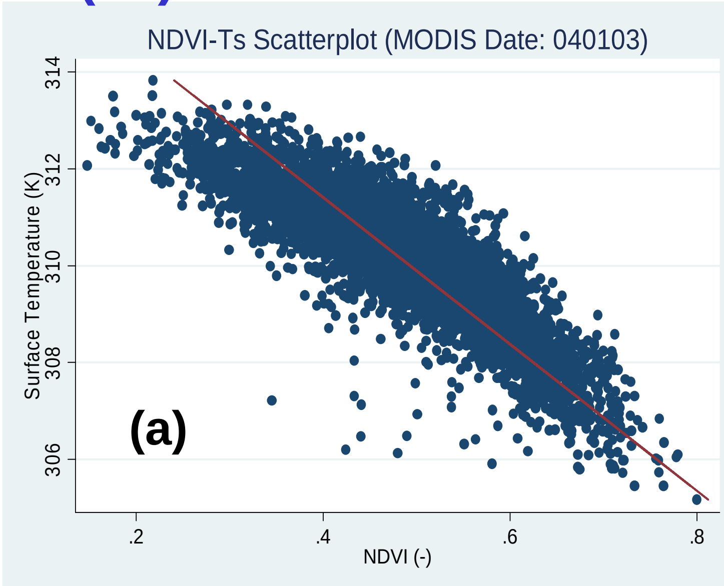
Methodology:
Surface Energy Balance for Land (SEBAL)



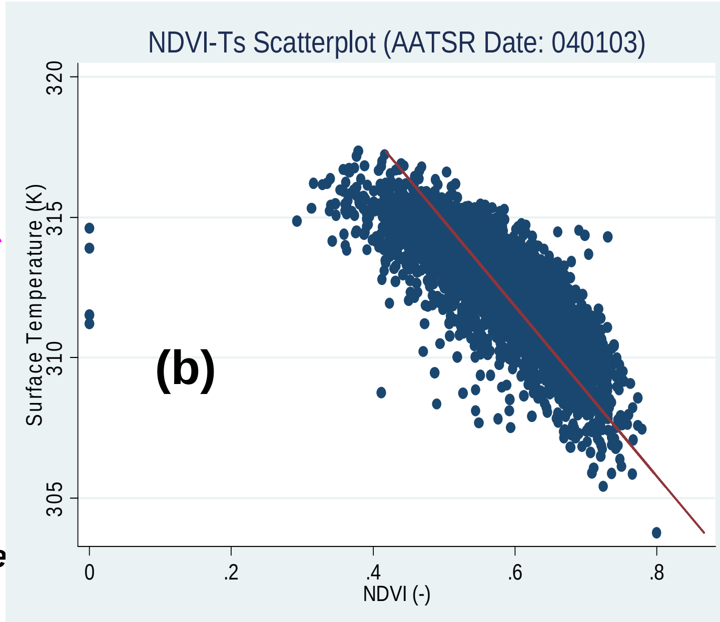
Source: Morse et al. (2000)

Remotely Derived SEBAL Inputs (1): NDVI & Land Surface Temperature (Ts)



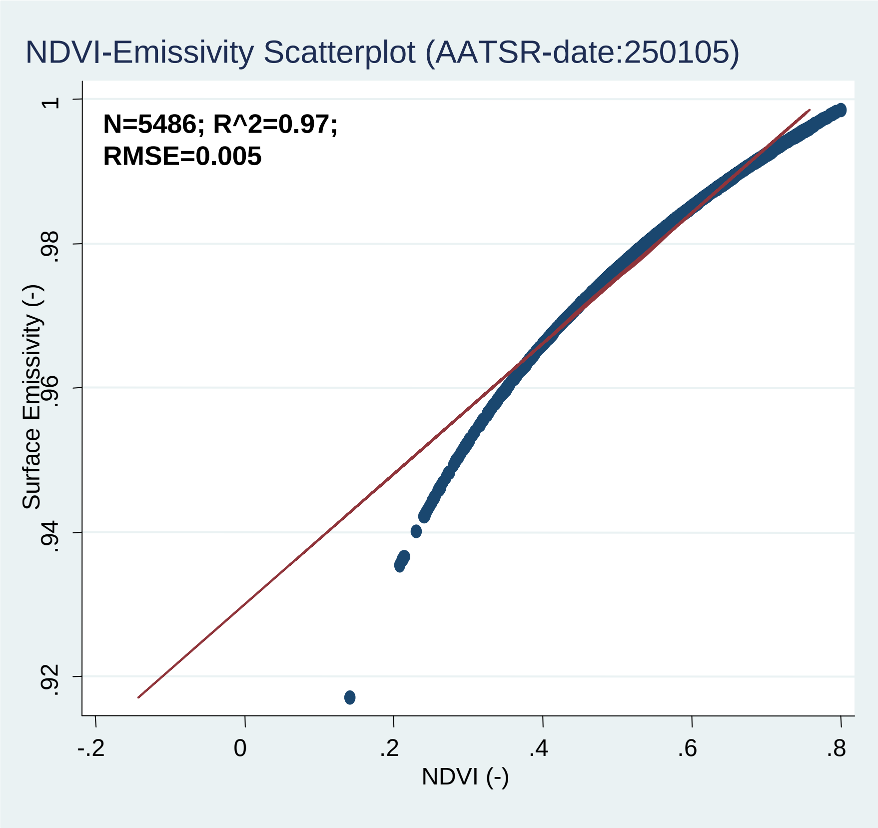


N = 5486; (a) $R^2 = 0.7458$;
RMSE = 0.051; (b) $R^2 = 0.6162$;
RMSE = 0.04993

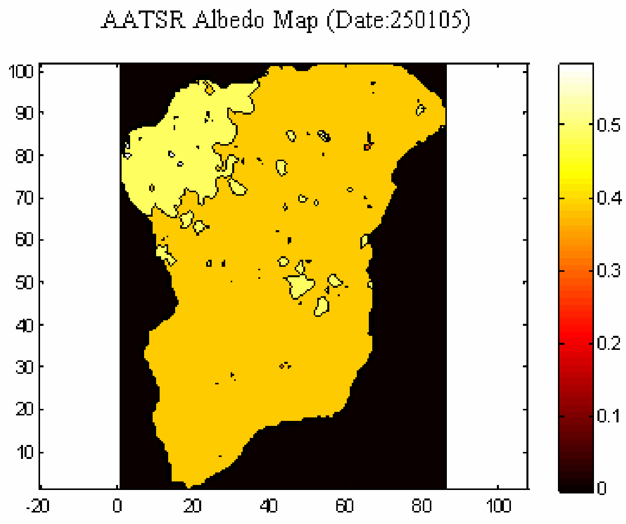


Remotely Derived SEBAL Inputs (2): Surface Emissivity & Albedo

(a) NDVI-Emissivity Model



(b) Surface Albedo Map



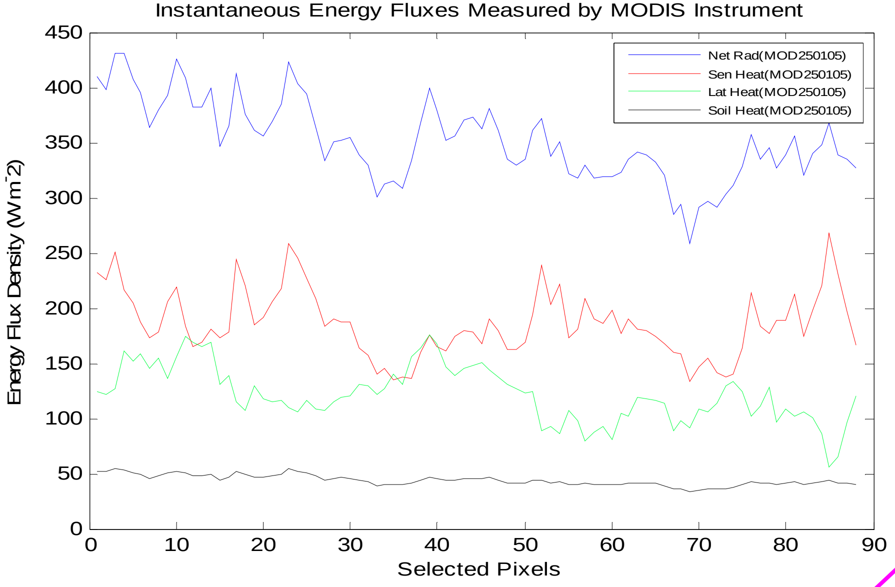
Albedo is highest in Tamale urban area and lowest in more vegetated areas

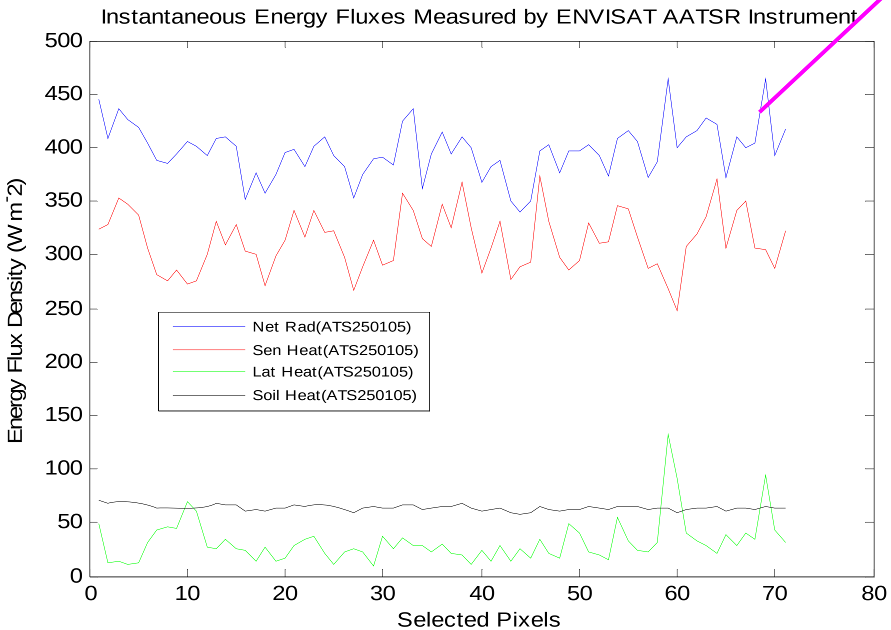
Summary of Current Results

- Surface flux models
- Distributed ET
- Sensor inter-comparison

Results (1)

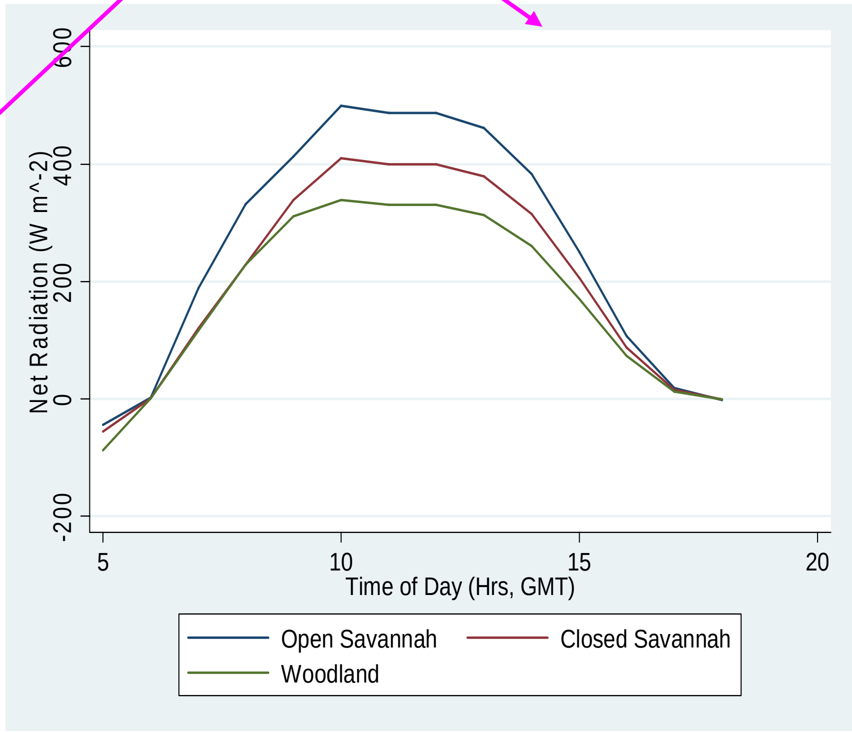
Diurnal Net Radiation Modelling





Bisht et al. (2005)

$$R_n(t) = R_{n-\max} \sin\left[\left(\frac{t - t_{rise}}{t_{set} - t_{rise}}\right)\pi\right]$$



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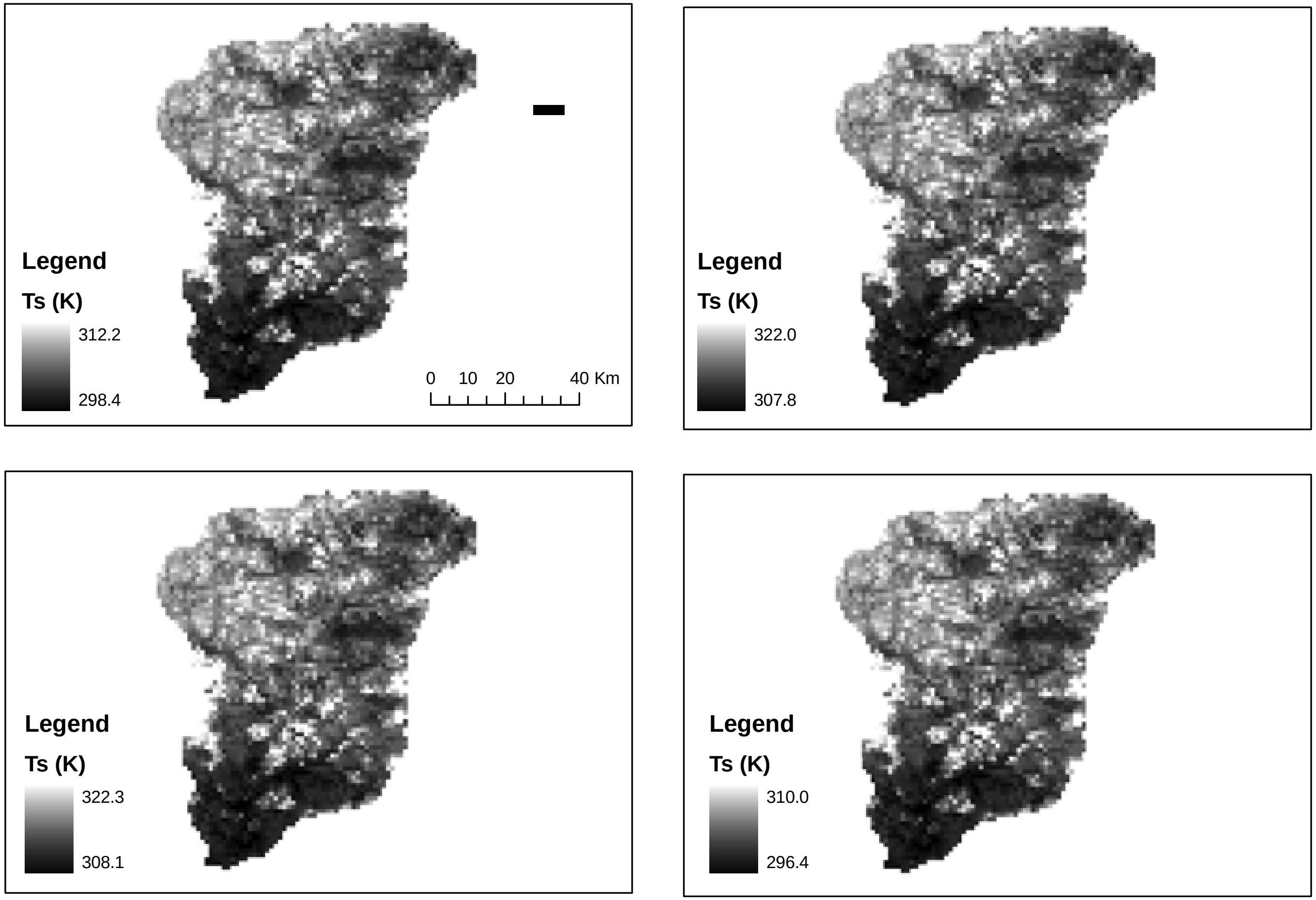
Results (2)
Diurnal Net Radiation

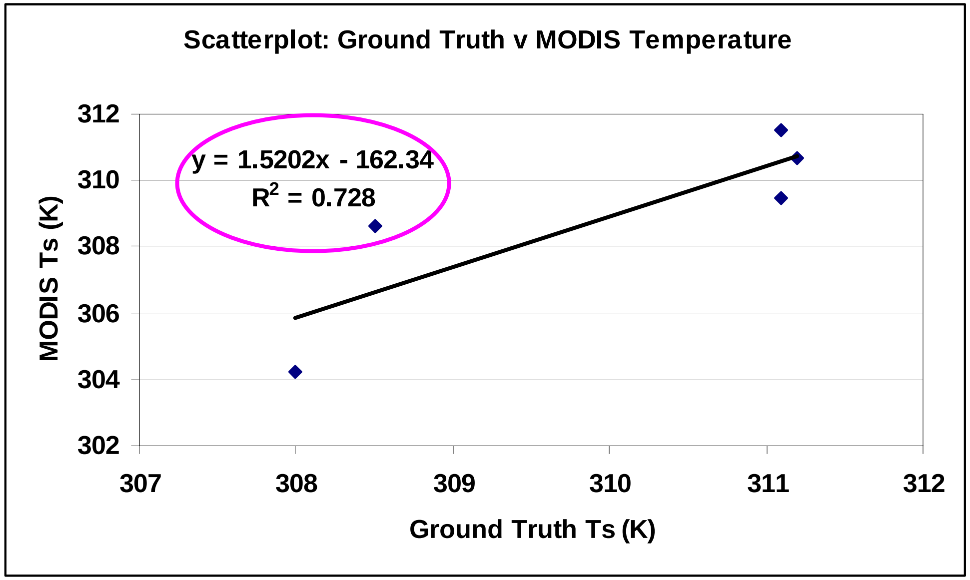
	MODIS	AATSR	OBS	Deviation (MODIS)	Deviation (AATSR)
Net Rad (Rn)	355	378	304	+51	+74
Sen heat (H)	200	300	150	+50	+150
Lat heat (LE)	136	68	142	-6	-74
Soil heat (Go)	49	24	71	-21	-47

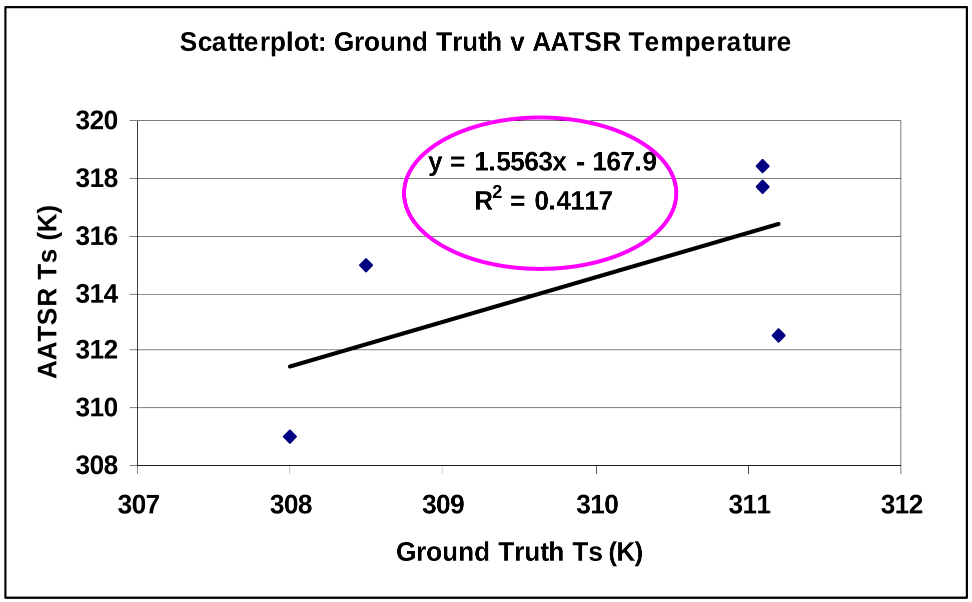
Energy units = W m^-2

Date 250105

Results (3)
Spatial Models of Surface Temperature



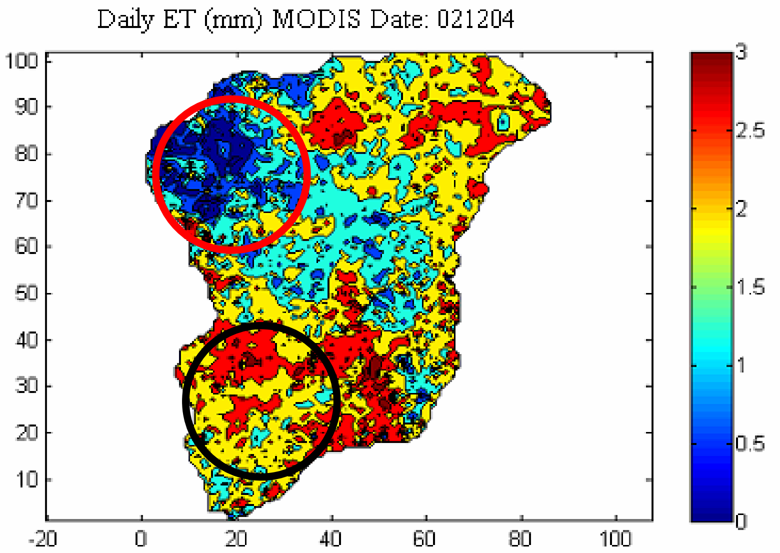


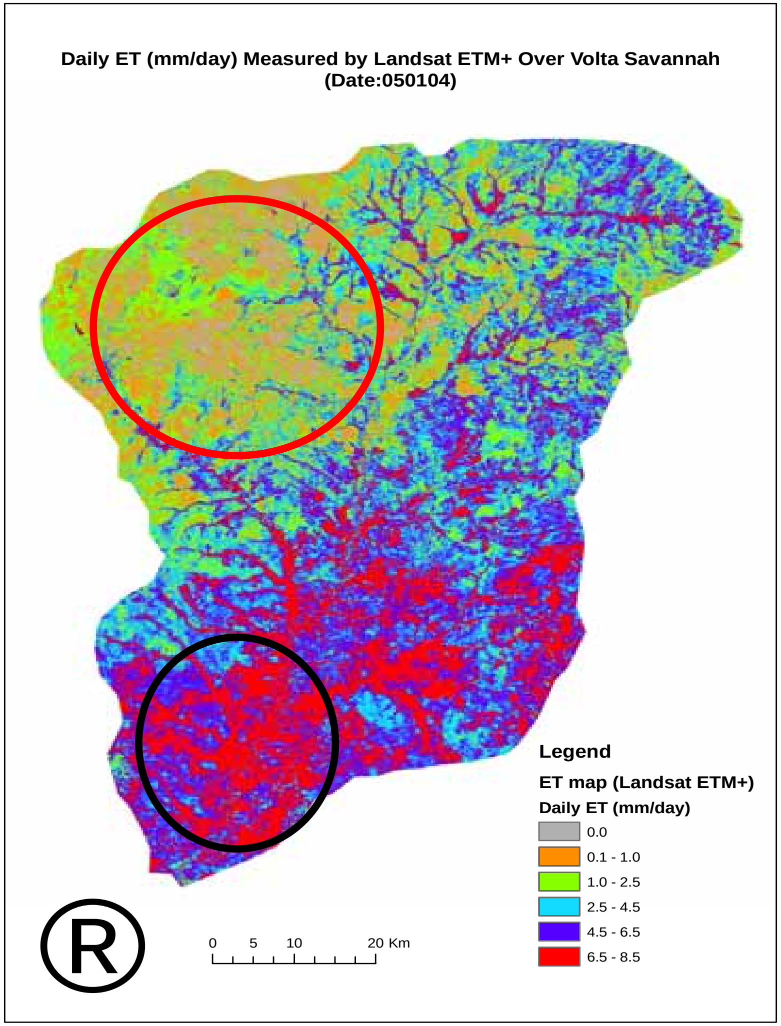


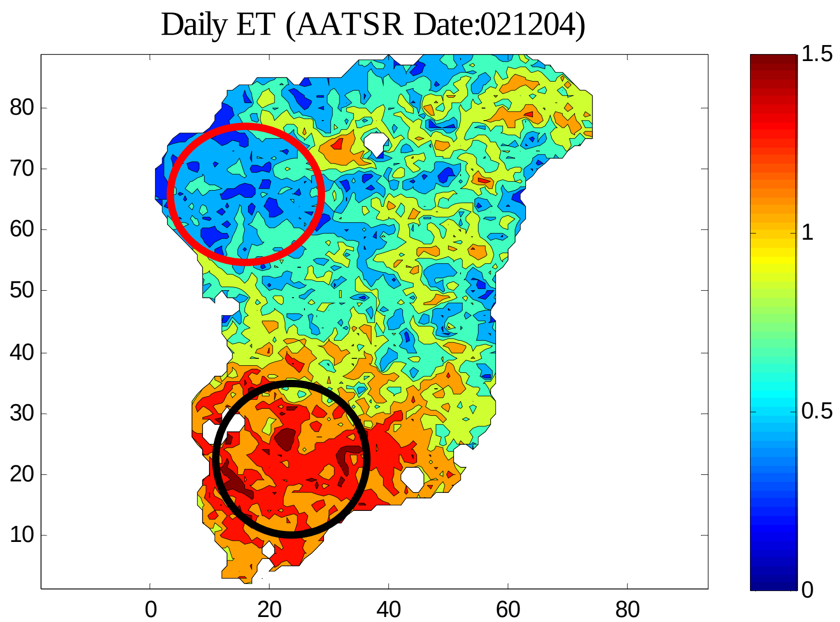
Results (4)

Validation of Satellite Temperatures

Results (5)
ET Spatial Models (mm/day)







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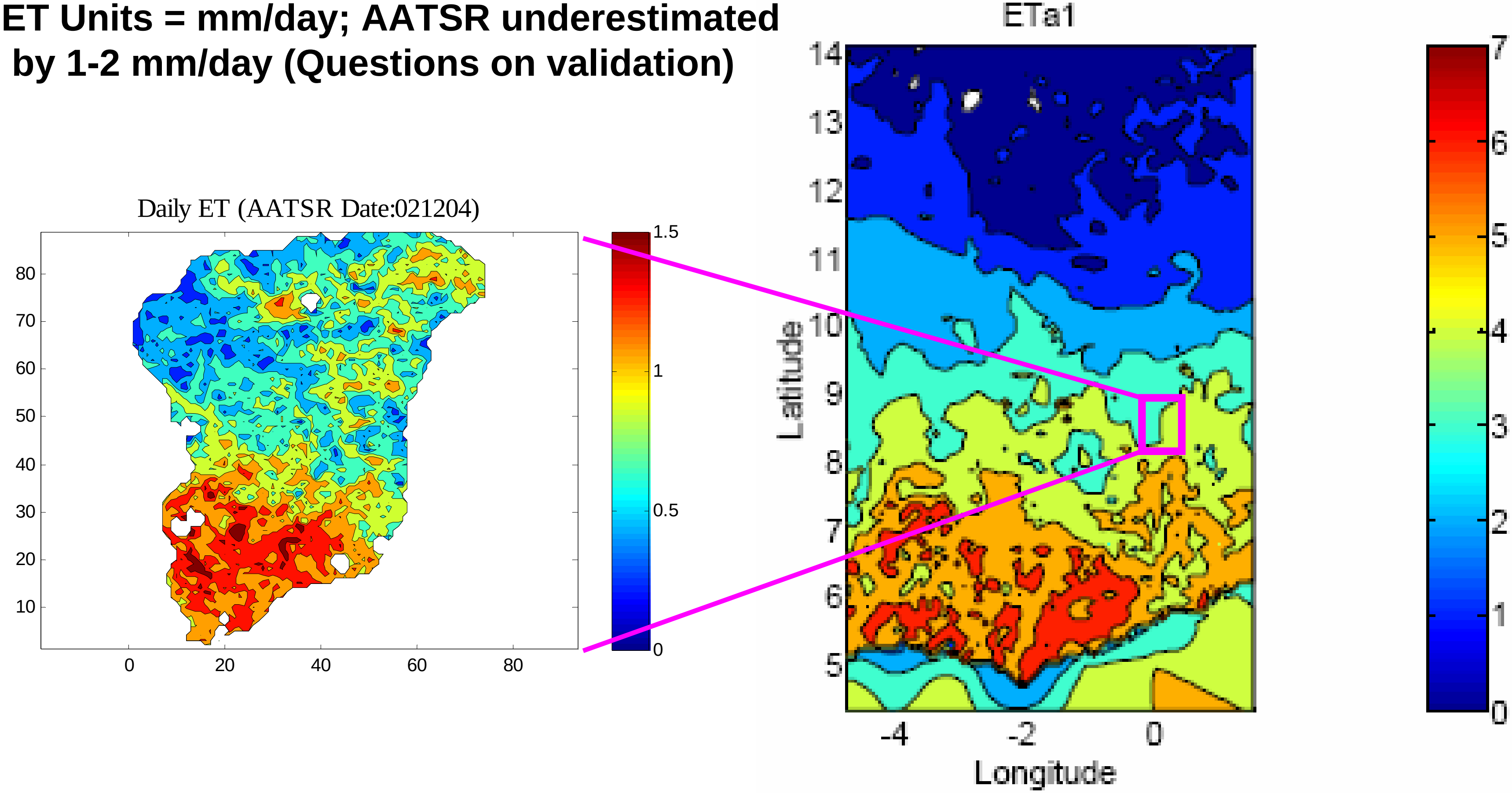
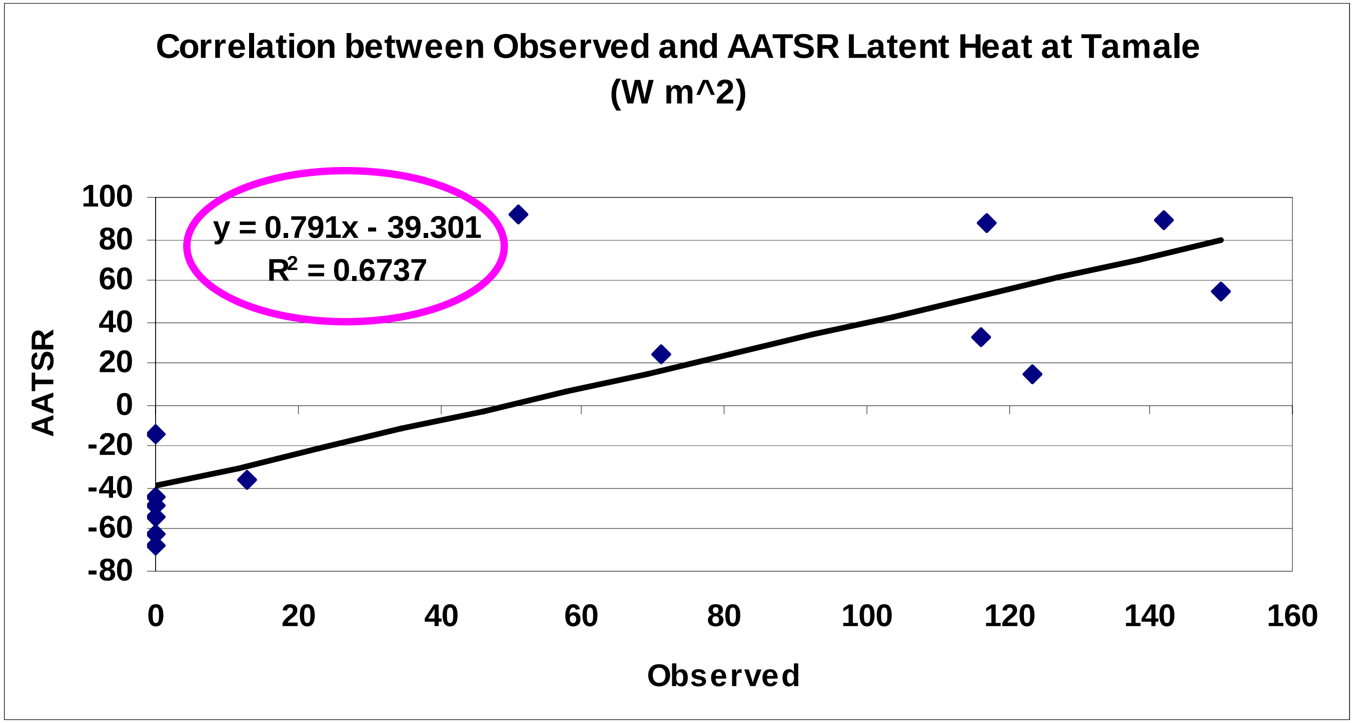
ET Validation: AATSR v GLOWA Data (1)

ET Units = mm/day; AATSR underestimated by 1-2 mm/day (Questions on validation)

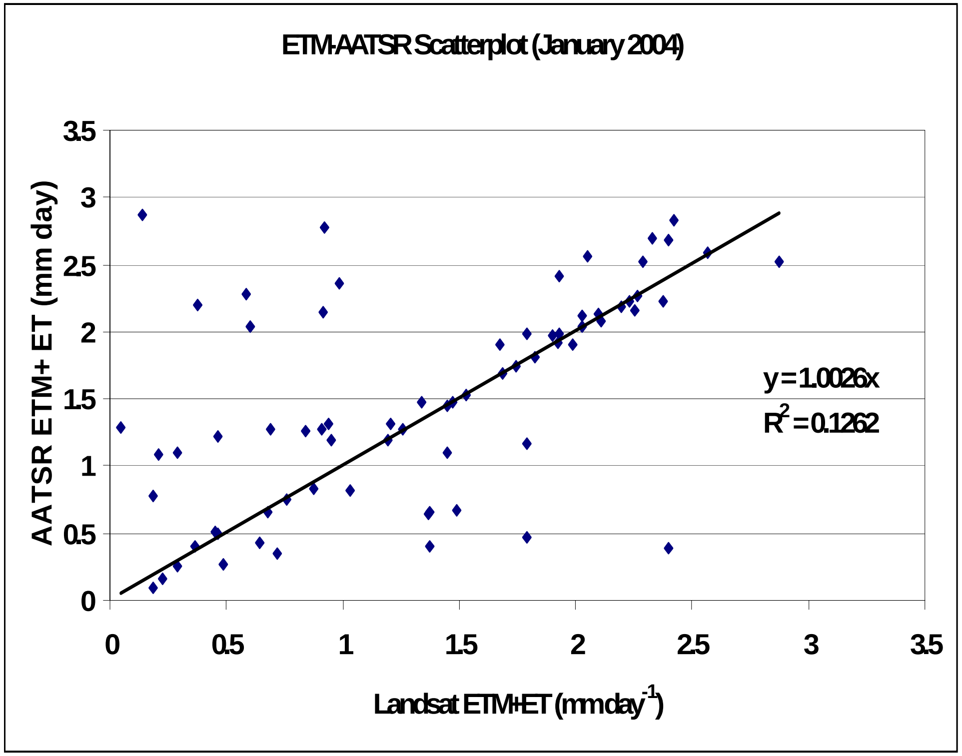


Local-scale ET validation (2)



MODIS: R^2 = 0.82

Spatial ET Validation & Satellite Sensors v Other Methods (3)



N = 71; R^2 = 0.13; RMSE = 0.2012

ET (mm^-day) for Tamale area observed by different methods

Method	Scale	Range	Mean	Std
P-Monteith	Local	1.53 – 4.87	3.18	0.66
Scintillo-meter	**Regional (1–5km)**	1.79 – 3.47	**2.96**	0.28
Landsat ETM+	**Regional**	0.15 – 2.93	**2.47**	0.42
MODIS	**Regional**	0.05 – 2.83	**2.01**	0.37
AATSR	**Regional**	0.01 – 2.09	**1.21**	0.86

Concluding Remarks

•West Africa is well-covered by recent satellite sensors e.g. ETM+, MODIS & AATSR

•Although these sensors cannot directly measure hydrological fluxes, they are extremely useful predictors of distributed land surface fluxes, e.g. land-cover, surface temperature, net radiation, ET, etc.

•Distributed surface fluxes have a variety of applications, e.g. metrics for climate change impacts on river basins, water balance modelling (water resources management), irrigation & agronomy, ecosystem modelling, etc.

•Much research remains, hydrological potential of MODIS quite well known but potential of AATSR needs further studies
E.g. (1) AATSR Level 2 data; (2) atmospheric correction; (3) data retrieval algorithms; (4) Validation of reflectance bands with MERIS

Potential Applications
(Challenges & Prospects)

•Integration into regional climate change models

•Regional water balance modelling (Ungauged catchments)

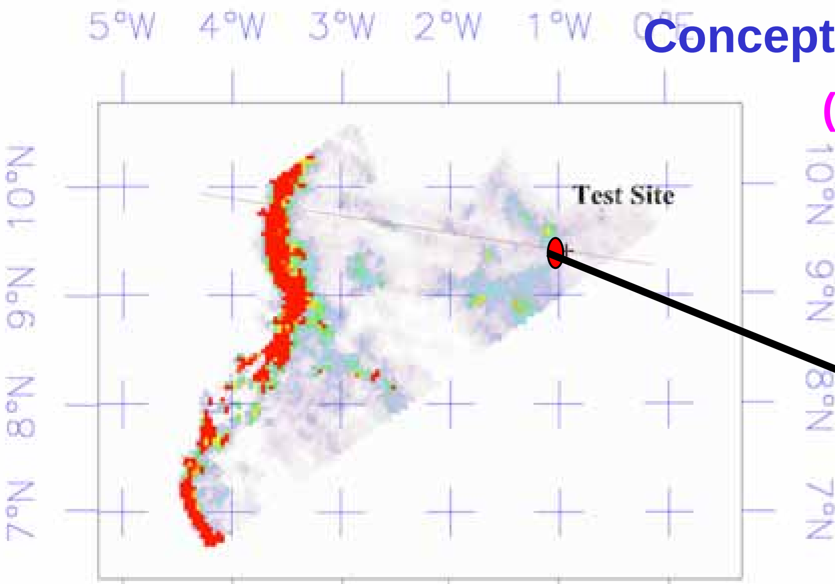
•Others, e.g. irrigation research, ecosystem modelling

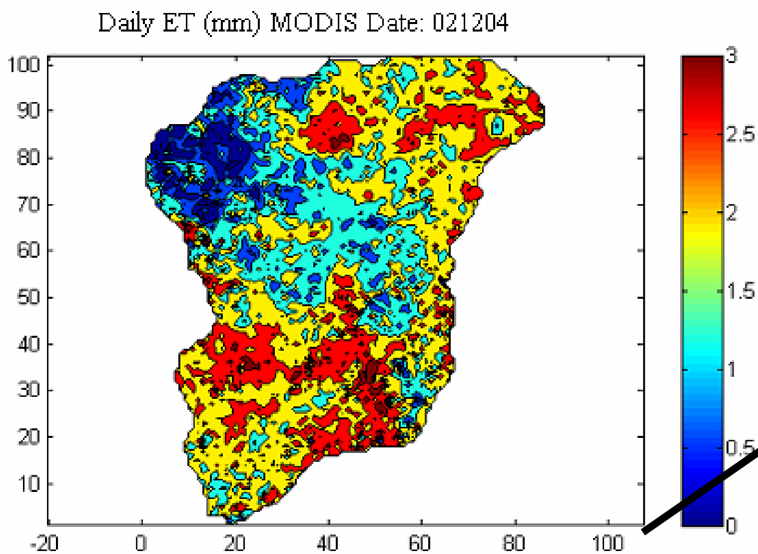
Big questions:
•Scale
•Ground validation
•Model fine-tuning, etc.

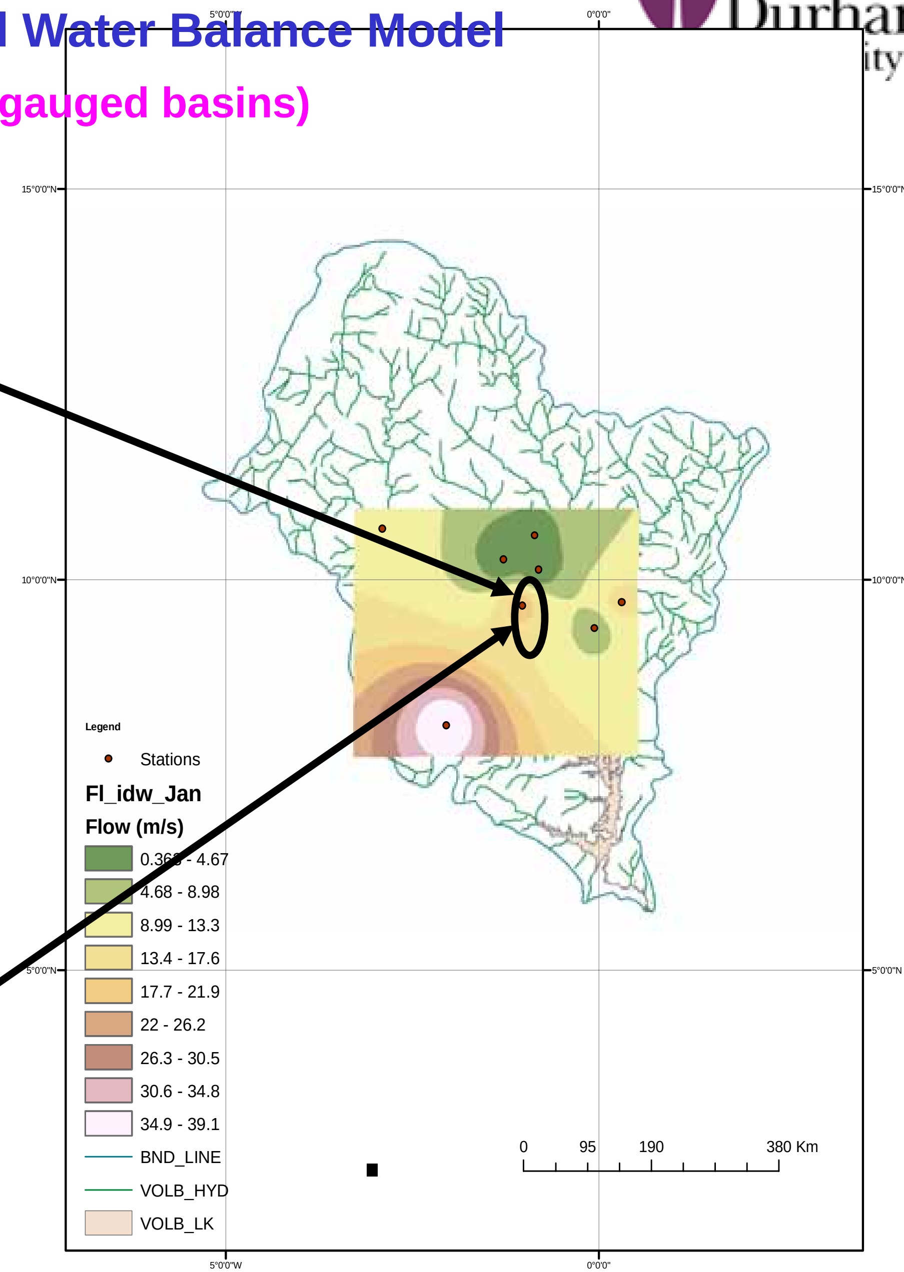
Prospects:
•Data assimilation in SEBAL is reasonably good
•Data & methodology are improving

Conceptual Water Balance Model

(Ungauged basins)







End of Presentation

Thank You