Downscaling of AMSR-E Soil Moisture Using Thermal Sensors and a Physically-Based Model

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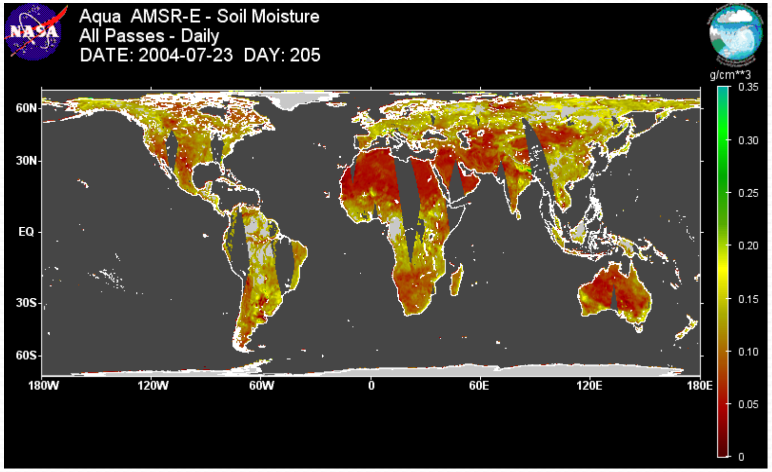
Introduction & Purpose

- Soil moisture is a critical variable for a wide variety of applications: hydrology, agriculture, climate change, and so on.
- The data is scarce; only in-situ point data can be found, and only in a small area.



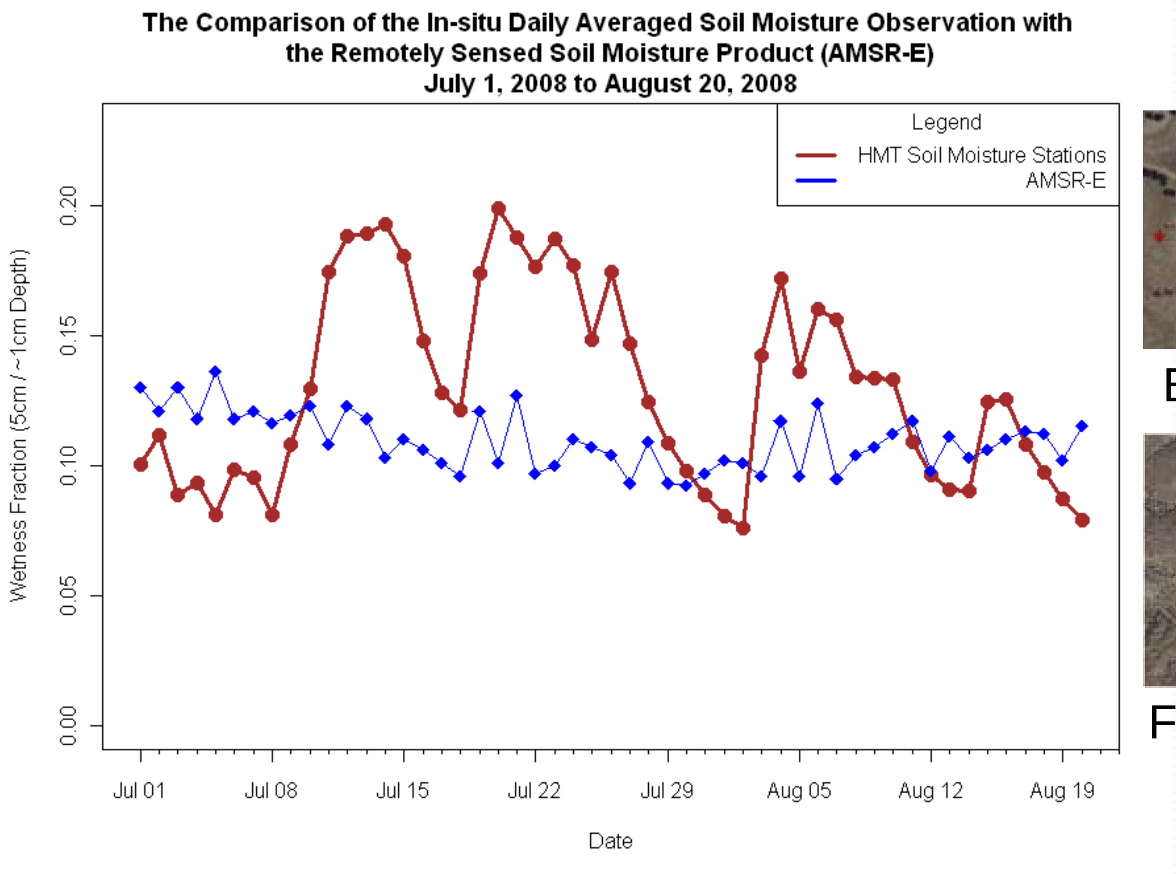
AMSR-E Daily Soil Moisture Product

The in-situ measurement at a NOAA soil moisture station

- **Purpose:**
  Examine utility of AMSR-E imagery for surface soil moisture mapping

Availability of AMSR-E Soil Moisture Data & Its Limitations

- AMSR-E: Based on X-band (centered at 10.7 GHz). Wavelength not long enough to penetrate > 1 cm earth and vegetation canopy.
- AMSR-E: Coarse resolution (~25 km; 1-2 times per day)



ELG

CNL

FMS

Three Steps

1. Downscale SM from 25 km to 5 km using a thermal sensor & Von Karman wind turbulence model
2. Downscale SM from 5 km to 1 km based on the accumulated infiltrated rainfall for the previous consecutive four days till current day
3. Downscale SM from 1 km to 500m based on the quantity of flow accumulation.

Energy Balance

Precipitation Infiltration

Geomorphology
(Flow Accumulation, &
Saturated Hydraulic
Conductivity)

Step 1 – Energy Balance

$$SM_{MODIS,5} = SM_{AMSR,25} + \frac{\partial SM}{\partial SEE} * \Delta SEE_{MODIS,5}$$

$$SM_5 = SM_{AMSR,25} + SM_c * SMP_{MODIS,5}$$

$$SMP_{MODIS,5} = \frac{T_{MODIS,25} - T_{MODIS,5}}{T_{MODIS,25} - T_{min\ MODIS,1}}$$

From Komatsu (2003):

$SMc = SM_{co} * (1 + \gamma / r_{ah})$

SMc0 is 0.01 for sand and 0.04 for clay.

$$r_{ah} = \frac{1}{k^2 u}\left[ln\left(\frac{Z}{z_{0m}}\right)\right]^2$$

Soil moisture model involves:

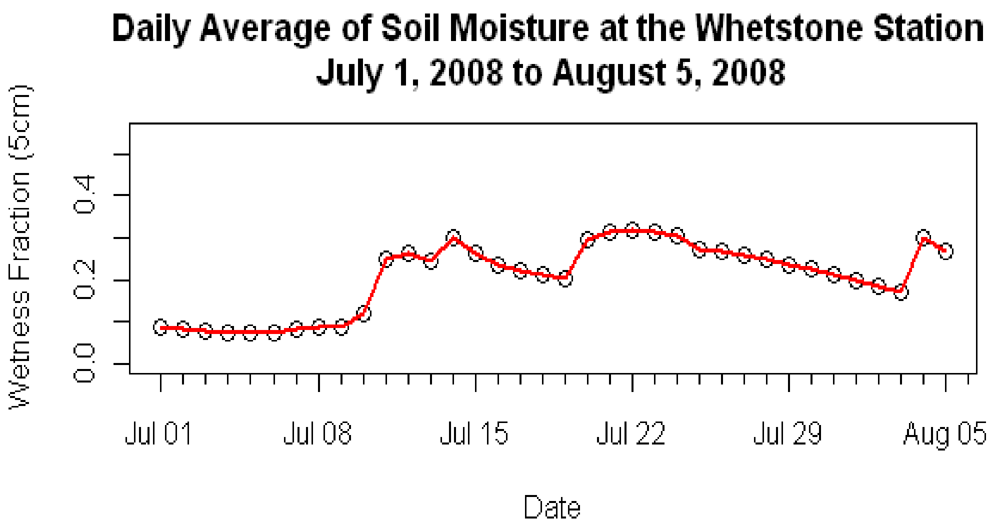
- Downscaling of AMSR-E imagery
- Adjustment based on:
  - MODIS imagery
  - von Karmann wind turbulence
  - soil properties (SSURGO).

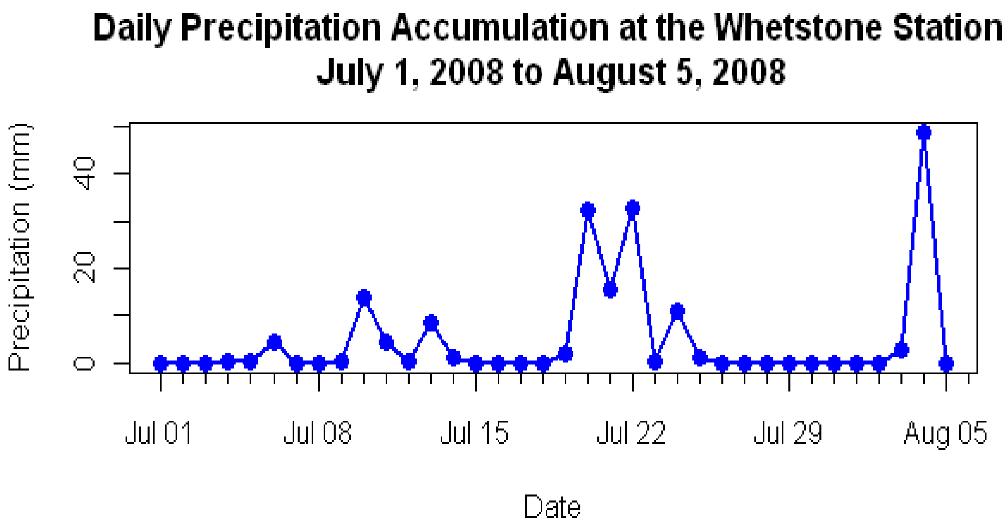
Step 1 – Energy Balance

- Deriving the soil temperature using MODIS surface temperature and a vegetation index.
- $T_{MODIS,n} = (T_{surf, MODIS,n} - f_{v,MODIS,n}*T_{v,n})/(1-f_{v,MODIS,n})$
- $f_{v, MODIS,n} = (EVI_{MODIS,n} - EVI_{min}) / (EVI_{max}-EVI_{min})$

- EVI_{min} & EVI_{max} being the NDVI value corresponds to bare soil and fully vegetated pixels respectively
- EVI was used instead of NDVI

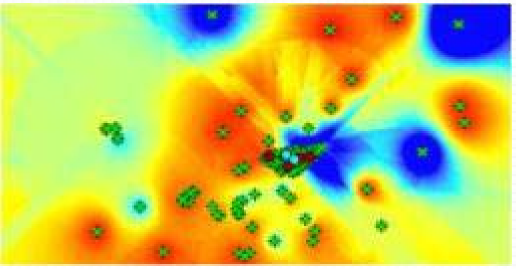
STEP 2 – Precipitation & Infiltration



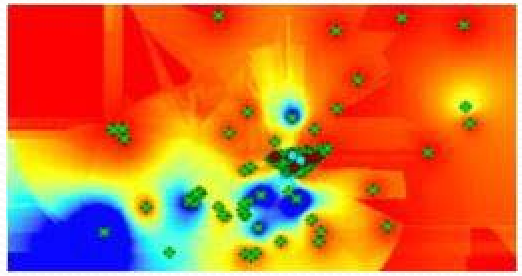


Whetstone Station

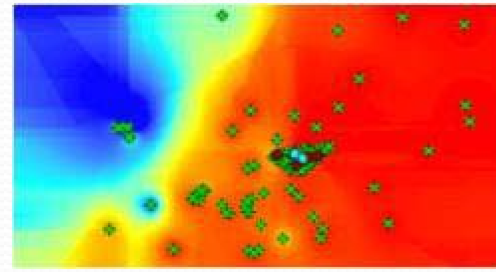
STEP 2 – Precipitation & Infiltration



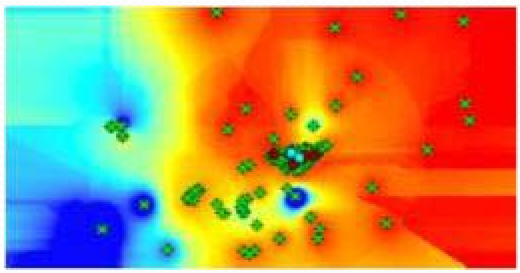
7/1 Precipitation



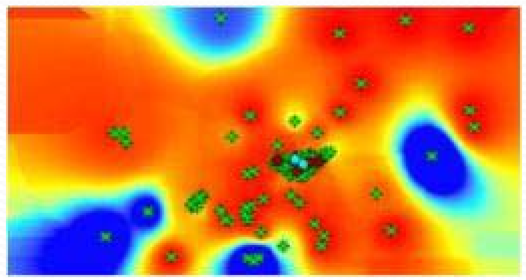
7/2 Precipitation



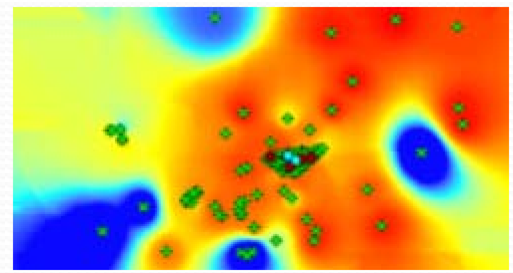
7/3 Precipitation



7/4 Precipitation



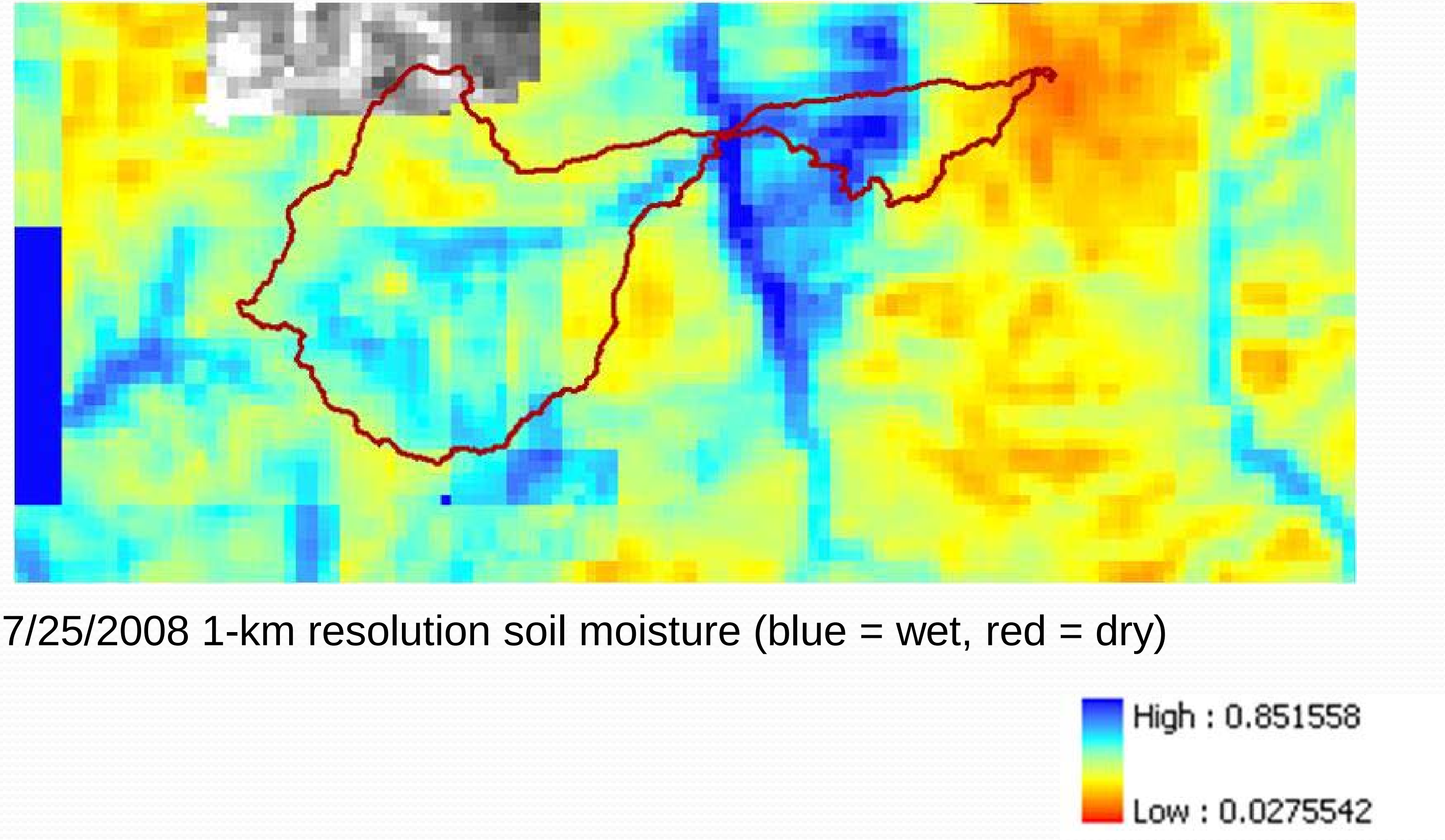
7/5 Precipitation



Accumulated Infiltrated Rain

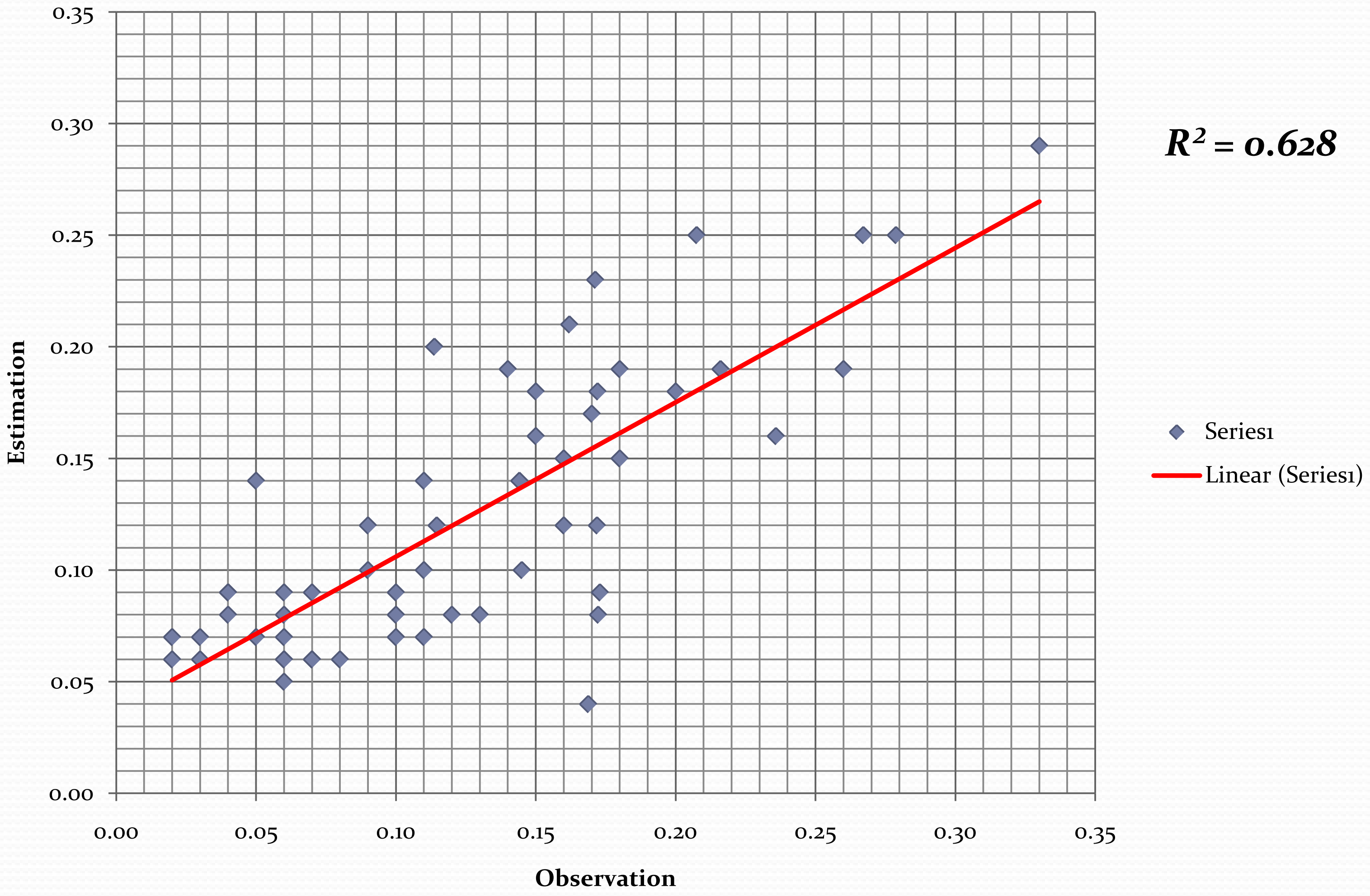
- Spatial interpolation of gage data (IDW)
- Infiltration accounting using Horton's equation
- Soil moisture contribution tabulated

Derived 1-km Soil Moisture



7/25/2008 1-km resolution soil moisture (blue = wet, red = dry)

Validation – Estimation vs. Observation



Conclusions

- Satellite soil moisture imagery (AMSR-E) has limited capacity to detect ground moisture conditions.
  - Dry surface conditions are detected better than wet conditions.
  - Surface depth of detection ~ 1 cm
- Downscaling of AMSR-E provides useful information when combined with :
  - MODIS Thermal IR
  - SSURGO soil properties
  - Antecedent precipitation
- Surface energy balance model provides means to estimate surface soil moisture and its spatial variability.
- Correlation to in-situ SM data is encouraging given data examined; more data set need to be studied.
- Automation of developed procedures is possible.

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Shei, Shei

Discussion?

:

Used MODIS EVI Instead of NDVI Data

$$EVI = 2.5 \times \frac{(NIR - RED)}{(NIR + C1 \times RED - C2 \times Blue + L)} * 1 + L$$

- C1 = 6.0
- C2 = 7.5
- L = 1.0
- Improve vegetation and background differentiation
- The use of blue band will correct the atmospheric aerosol scattering effect happening in red band.
- The fv is much improved.

STEP 2

- $SM_{1km} = SM_{5km} + \text{Adjusted } SMc,_{1km} * (\text{Infiltration} - \text{mean}(\text{Infiltration}))_{1km} / SD(\text{infiltration})_{1km}$
- The stomatal resistance, r_l, of a single leaf has a value of about 100 s m^{-1} under well-watered conditions. By assuming a vegetation height of 0.17 m, the surface resistance, r_s [s m^{-1}], γ becomes around 60 s/m.

Validation

07/05/2008

Station	RG3_WGEW	RG13_WGEW	RG14_WGEW	RG18_WGEW	RG20_WGEW	RG34_WGEW	RG37_WGEW	RG40_WGEW	RG46_WGEW
Observation	0.10	0.10	0.07	0.04	0.07	0.04	0.03	0.08	0.06
Estimation	0.08	0.07	0.09	0.09	0.06	0.09	0.07	0.06	0.06

RG401	RG405	Freeman Spring (%)	Elgin (%)	Whetstone (%)	Kendall SoilHydrology & RG82	LuckyHill Trench TDR	LuckyHill Soil Hydrology & RG83	SCAN WGEW
0.11	0.06	0.06	0.04	0.07	0.13	0.06	0.05	0.03
0.07	0.05	0.08	0.08	0.06	0.08		0.07	0.06

Validation

Location	Estimation		Observation	
FMS	Derived Soil Moisture at the cell Where FMS Located	0.14	Observed Average Soil Moisture @ FMS	0.14
ELG	Derived Soil Moisture at the cell Where ELG Located	0.09	Observed Average Soil Moisture @ ELG	0.11
WSE	Derived Soil Moisture @ the cell where WSE locate	0.21	Observed Soil Moisture @ WSE	0.30
SCAN & Lucky Hill Meteorological Station	Derived Soil Moisture @ the cell where SCAN & Lucy Hill Meteo. sites Located	0.17	Observed Average Soil Moisture @ SCAN Site & Lucky Hill Meteo.	0.18
RG003 & RG076	Derived Soil Moisture @ the cell where RG003 and RG076 locate	0.32	Observed Average Soil Moisture @ RG003 & RG076	0.26
RG013	Derived Soil Moisture @ the cell where RG013 located	0.24	Observed Soil Moisture @ RG013	0.28
RG014 & RG018	Derived Soil Moisture @ the cell where RG014 & RG018 located	0.24	Observed Average Soil Moisture @ RG014 & RG018	0.19
RG034	Derived Soil Moisture @ the cell where RG034 located	0.26	Observed Soil Moisture @ RG034	0.27