WATER AND ENERGY BALANCE ESTIMATION IN PUERTO RICO USING SATELLITE REMOTE SENSING

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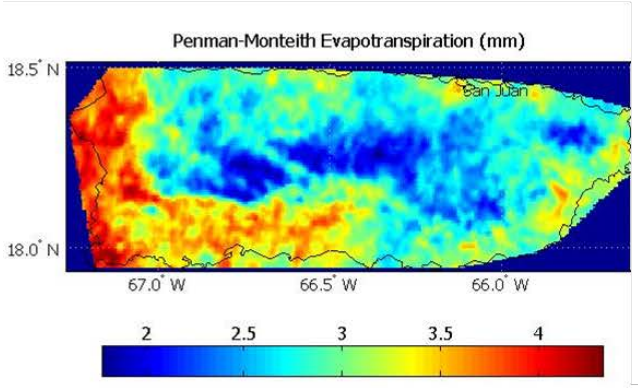
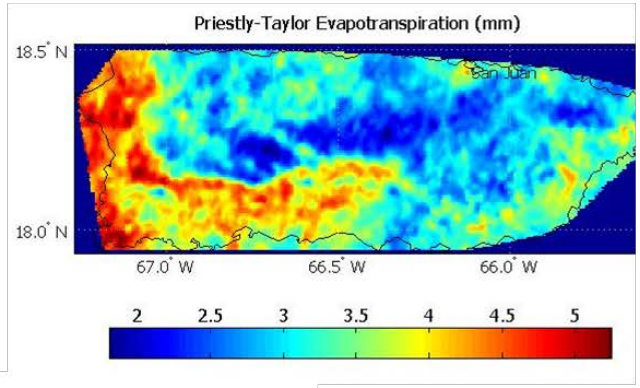
USDA
Hatch

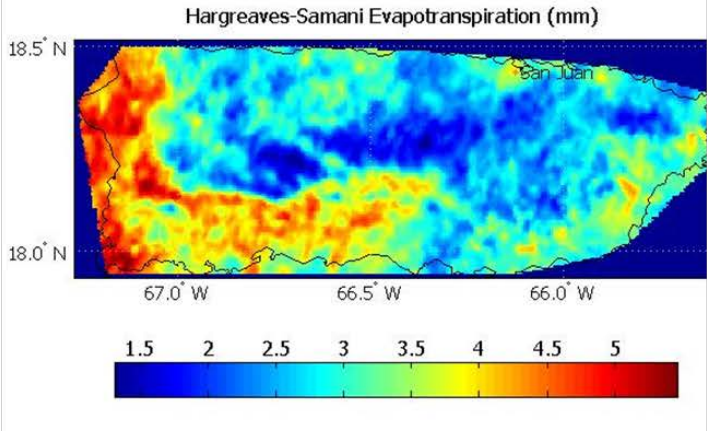
http://academic.uprm.edu/abe/PRAGWATER/

LAST YEAR'S OBJECTIVE

To develop an algorithm for estimating daily, high resolution (1-km), crop reference evapotranspiration (ET_o) over Puerto Rico.







$$ET_a = K_c\, ET_o$$

THIS YEAR'S OBJECTIVES

- To introduce several new water resource-related remote sensing products for Puerto Rico, Haiti and the Dominican Republic.

- The development of the methodology has advanced more quickly in Puerto Rico, therefore, the information presented here can be considered a prototype of what is being developed for the other two countries (i.e., Haiti and the Dominican Republic).

Technical Approach

Algorithm Flow Chart

$SM_2 =$
$Precip - ET_a - RO - DP - SM_1$

Obtain Solar Radiation, wind speed, rainfall, etc,. for yesterday

Expand the components of the Surface Energy Budget

Solve Surface Energy Budget implicitly in terms of the Effective Surface Temperature

$R_{net} + \lambda E + H + G = 0$

Estimate the components of the surface energy budget

Estimate Actual Evapotranspiration (ET_a)

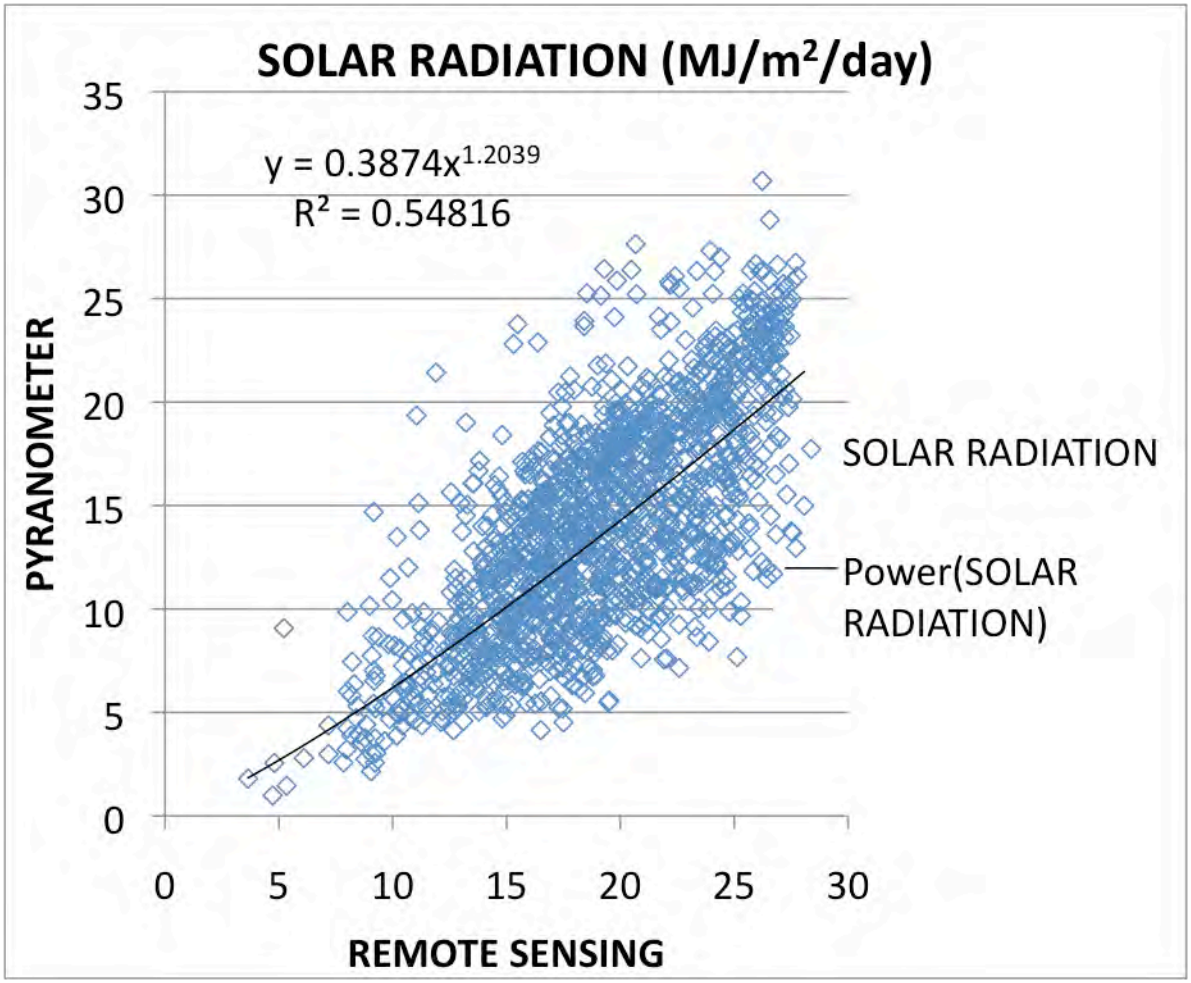
Estimate Components of the Surface Water Budget

Remotely Sensed Solar Radiation

Solar radiation was obtained using the Modified Gautier and Diak method (Gautier et al., 1980; Diak and Gautier, 1983).

Data were obtained from the GOES-East satellite.
Geostationary platform
1 km resolution for Puerto Rico
2 km Haiti and the Dominican Republic
High time resolution (30 minutes)

- **Comparison of daily integrated solar radiation obtained from pyranometers at six locations in Puerto Rico and satellite remote sensing. Data collected between March 2009 and June 2010**



Estimated Variables

- Reference evapotranspiration
- Net Radiation
- Latent heat flux
- Sensible heat flux
- Actual evapotranspiration
- Evapotranspiration "Crop" coefficient
- Surface runoff (Curve Number method)
- Deep percolation (based on field capacity concept)
- Soil moisture content (based on field capacity concept)

Transient Input Parameters and Variables

- Solar Radiation
- Rainfall
- Wind speed
- Vapor pressure
- Air temperature
- Effective surface temperature
- Bulk surface resistance
- Aerodynamic resistance

Non-Transient Input Parameters

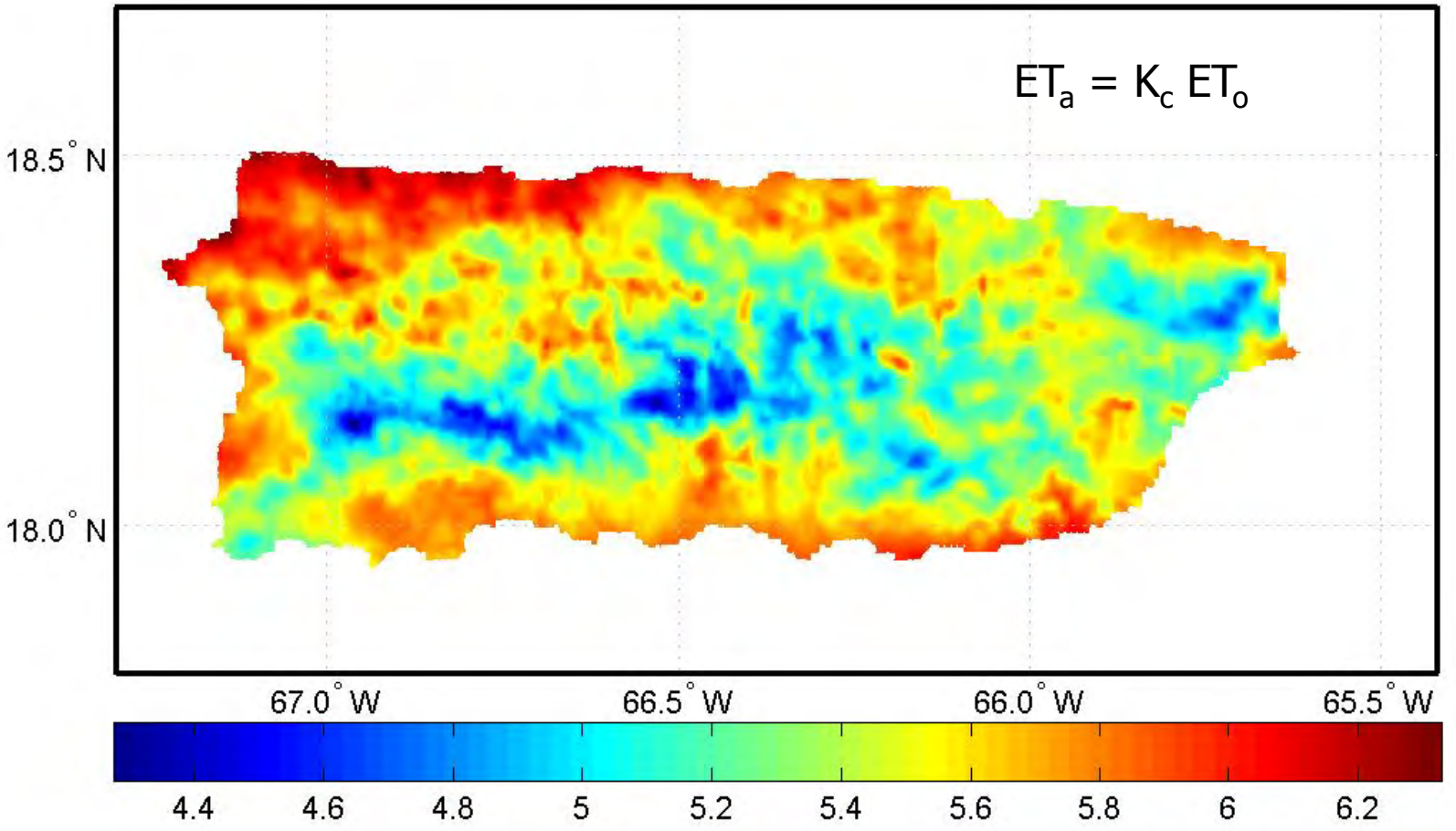
- Surface elevation
- Soil texture
- Soil field capacity
- Soil wilting point
- Rooting depth
- Roughness length
- Zero plane displacement

RESULTS

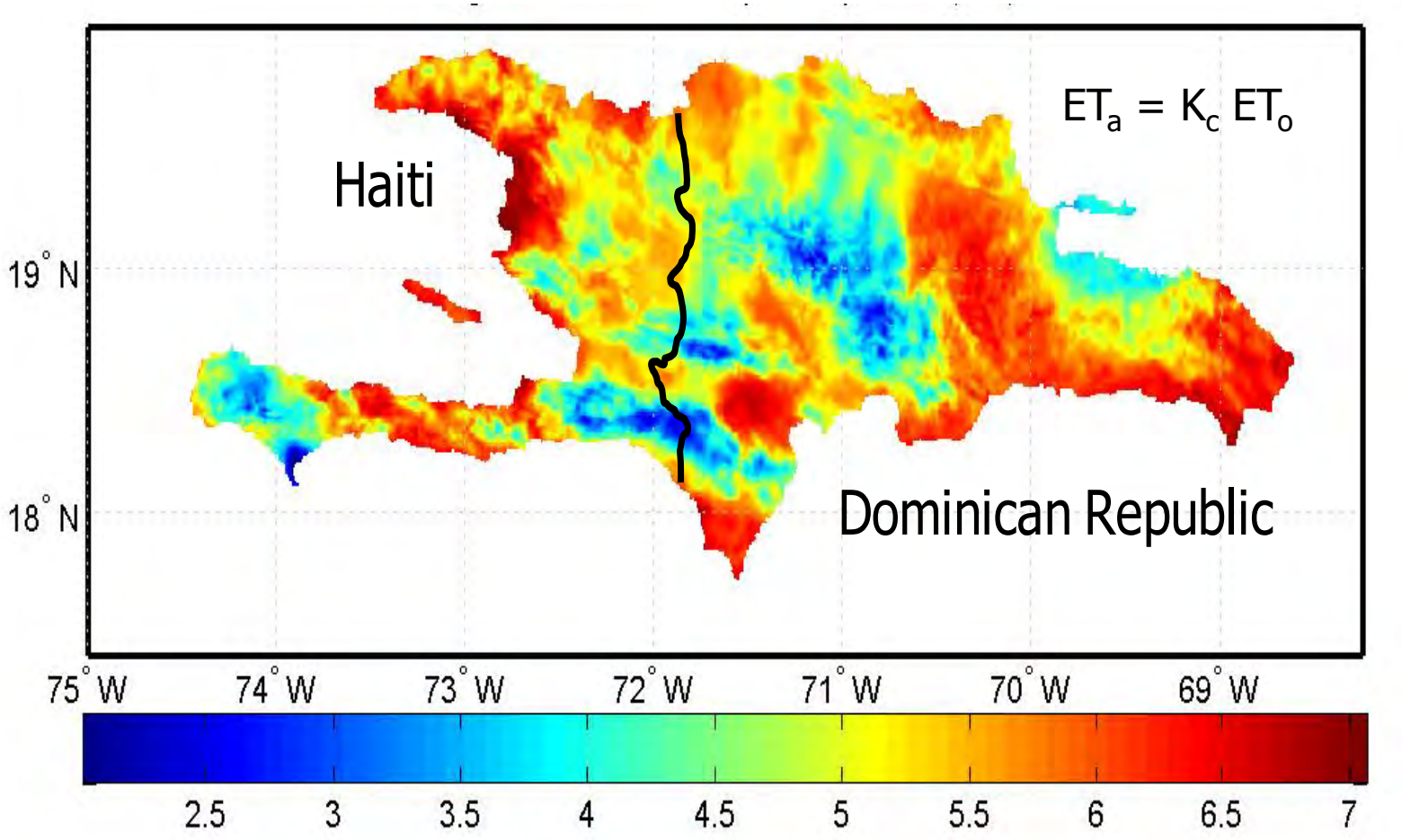
Reference Evapotranspiration for PR, Dominican Republic and Haiti

- Radiation-based Hargreaves formula is used

Estimated reference evapotranspiration (ET_o) for Puerto Rico on June 29th, 2010.



Estimated reference evapotranspiration (ET_o) for Haiti and the Dominican Republic on June 29th, 2010.

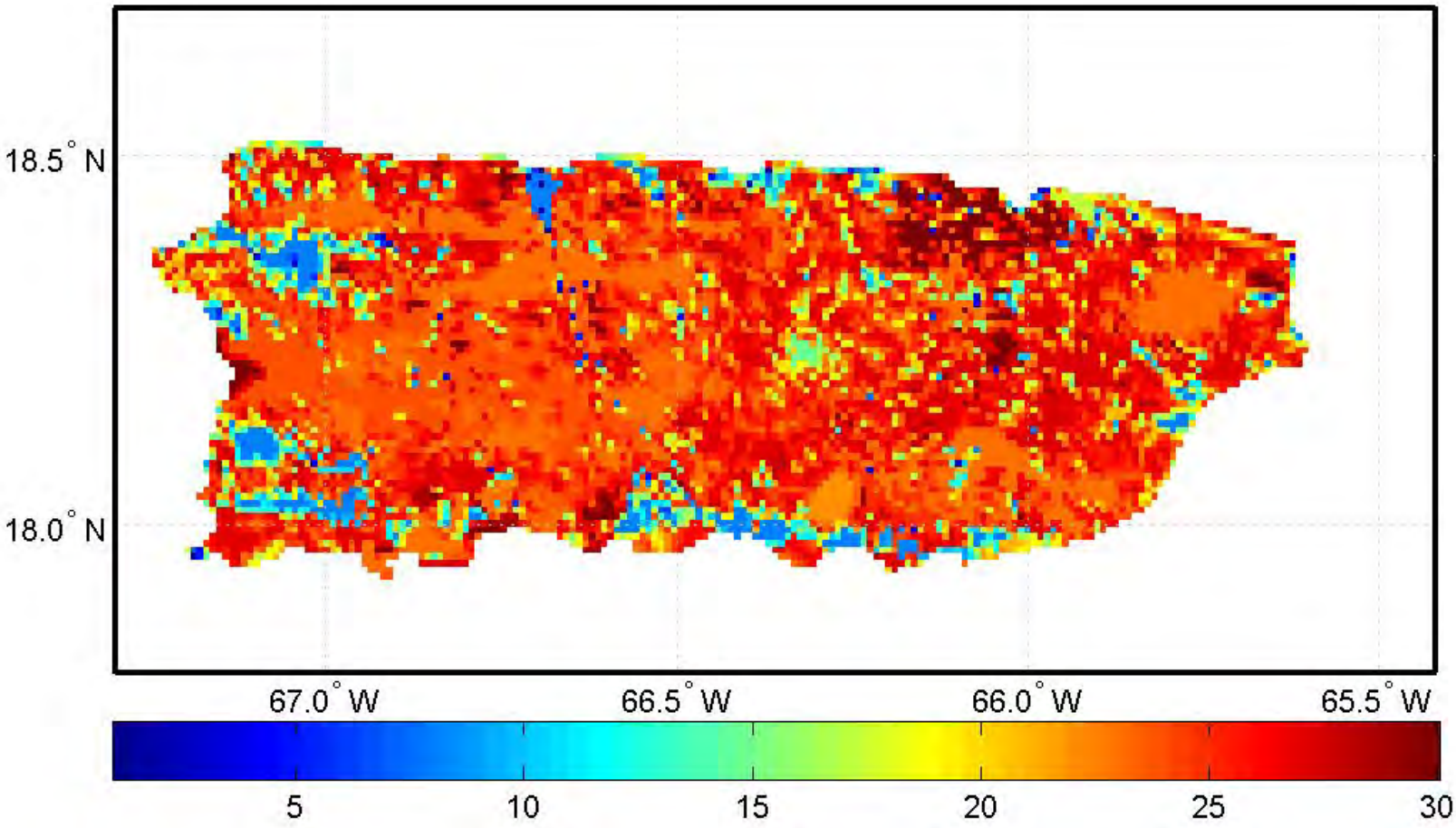


RESULTS – Actual ET and the Water and Energy Budgets for PR

- An analysis was performed for a10 day period between June 20 and June 29, 2010.
  - The soil moisture was adjusted daily based on the surface water balance
  - Images are shown for June 29, 2010

Land Cover Land Use Map

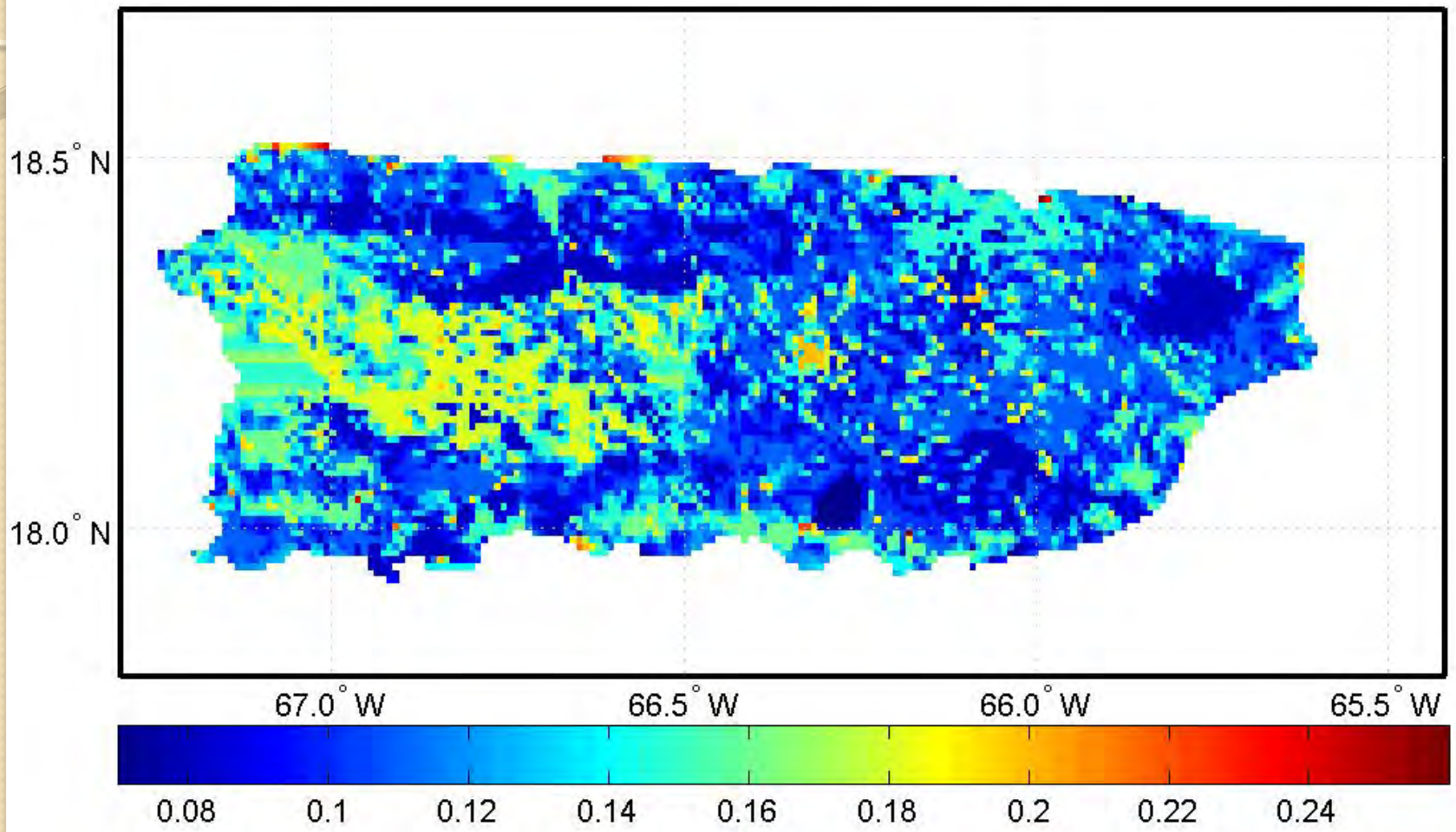
(Obtained from RAMS Surface Characteristics Dataset, http://bridge.atmet.org/users/data.php)



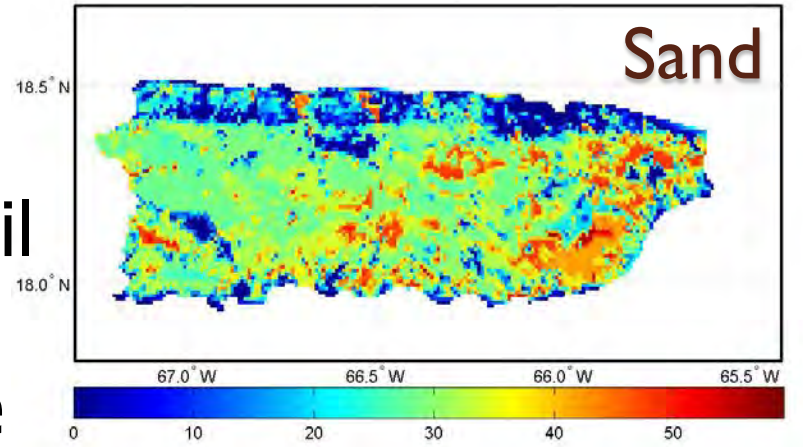
Land Cover Land Use Map (Obtained from RAMS Surface Characteristics Dataset, http://bridge.atmet.org/users/data.php)

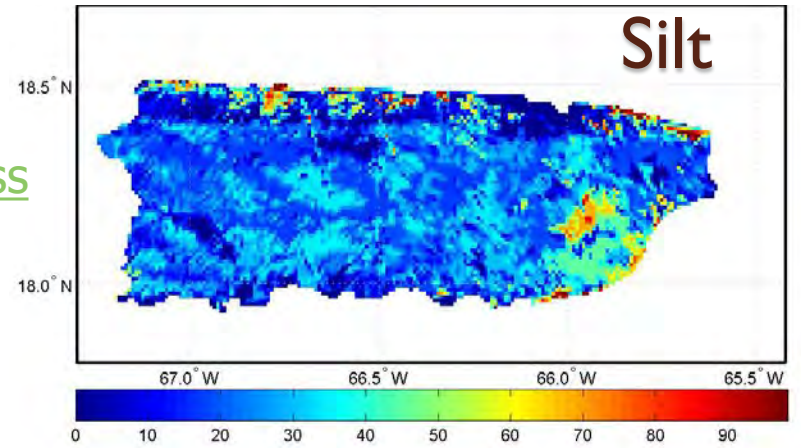
albedo	emiss	LAI	vfrac	zo	zdisp	rootdep	LAND CLASS #
0.14	0.99	0	0	0	0.1	0	0 Ocean
0.14	0.99	0	0	0	0.1	0	1 Lakes rivers stre
0.4	0.82	0	0	0.01	0.1	0	2 Ice cap/glacier
0.1	0.97	6	0.8	1	15	1.5	3 Evergreen needlelea
0.1	0.95	6	0.8	1	20	1.5	4 Deciduous needlelea
0.2	0.95	6	0.8	0.8	15	2	5 Deciduous broadleaf
0.15	0.95	6	0.9	2	20	1.5	6 Evergreen broadleaf
0.26	0.96	2	0.8	0.02	0.2	1	7 Short grass
0.16	0.96	6	0.8	0.1	1	1	8 Tall grass
0.3	0.86	0	0	0.05	0.1	1	9 Desert
0.25	0.96	6	0.1	0.1	0.5	1	10 Semi-desert
0.2	0.95	6	0.6	0.04	0.1	1	11 Tundra
0.1	0.97	6	0.8	0.1	1	1	12 Evergreen shrub
0.2	0.97	6	0.8	0.1	1	1	13 Deciduous shrub
0.15	0.96	6	0.8	0.8	20	2	14 Mixed woodland
0.2	0.95	6	0.85	0.06	0.7	1	15 Crop/mixed farming
0.18	0.95	6	0.8	0.06	0.7	1	16 Irrigated crop
0.12	0.98	6	0.8	0.03	1	1	17 Bog or marsh
0.06	0.97	6	0.8	0.98	10.2	1	18 Evergreen needlelea
0.08	0.95	6	0.9	2.21	20.7	1.2	19 Evergreen broadleaf
0.06	0.95	6	0.8	0.92	9.2	1	20 Deciduous needlelea
0.09	0.95	6	0.8	0.91	7.2	1.2	21 Deciduous broadleaf
0.07	0.96	6	0.8	0.87	6.5	1.1	22 Mixed cover
0.08	0.96	5.7	0.8	0.83	7.4	1	23 Woodland
0.18	0.96	5	0.8	0.51	3.6	1	24 Wooded grassland
0.1	0.97	5.1	0.63	0.14	1.4	0.7	25 Closed shrubland
0.12	0.97	6	0.22	0.08	0.2	0.6	26 Open shrubland
0.11	0.96	2.6	0.73	0.04	0.2	0.7	27 Grassland
0.1	0.95	6	0.84	0.11	0.2	0.7	28 Cropland
0.16	0.86	0.7	0.07	0.05	0.2	0.5	29 Bare ground
0.15	0.9	4.8	0.74	0.8	1.1	0.8	30 Urban and built up

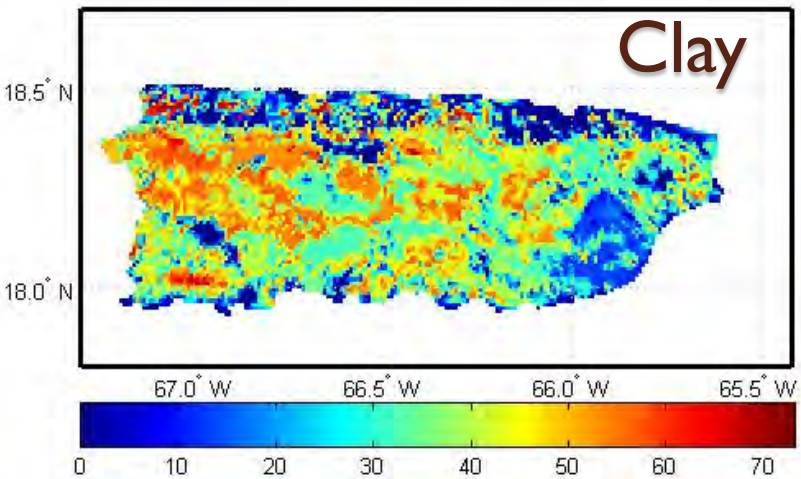
Average Surface Albedo for Puerto Rico



Percentages of sand, silt and clay for Puerto Rico were obtained from the Soil Survey Geographic (SSURGO) Database of the USDA Natural Resource Conservation Service (http://soils.usda.gov/survey/geography/ssurgo/).

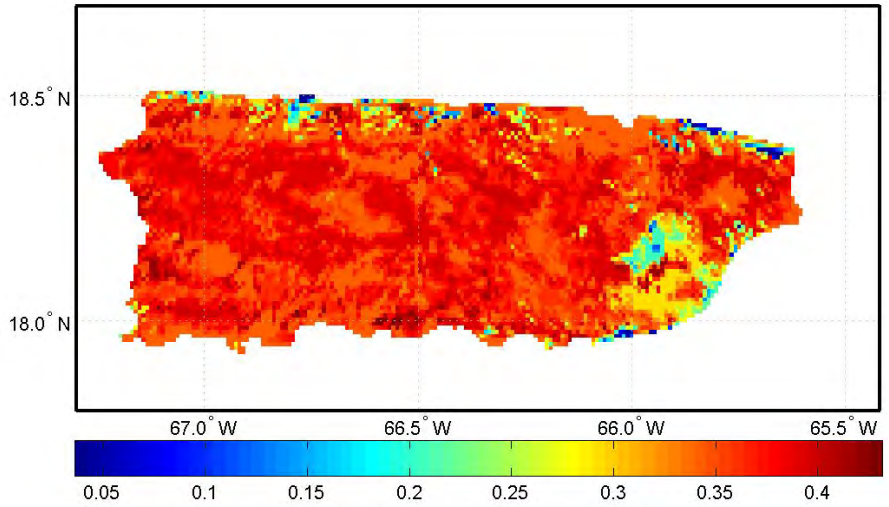




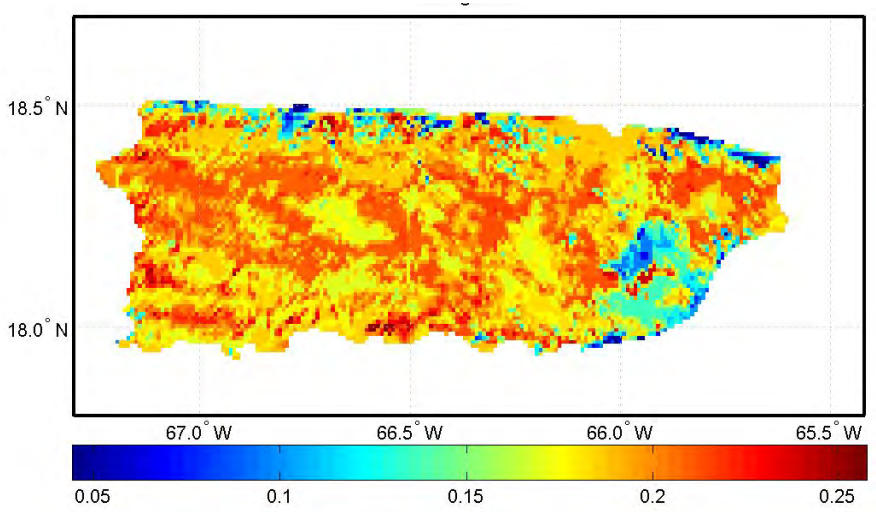


Values of field capacity and wilting point were obtained from regression equations based on percent sand, silt and clay presented by Cemek et al. (2004).

Field Capacity

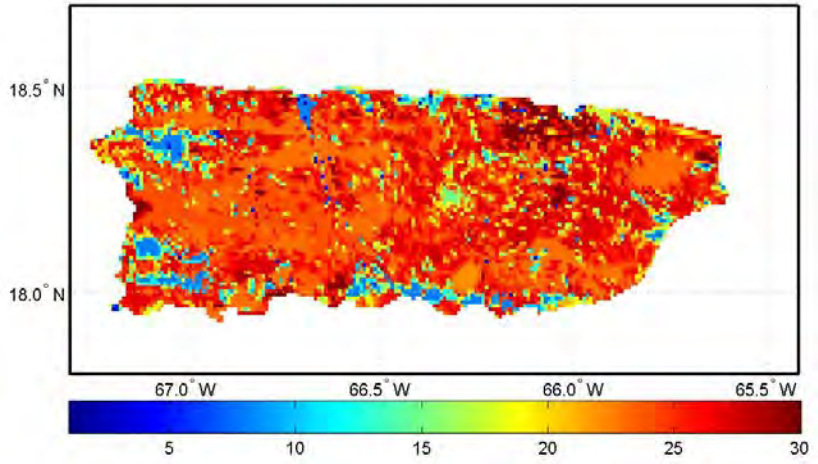


Wilting Point

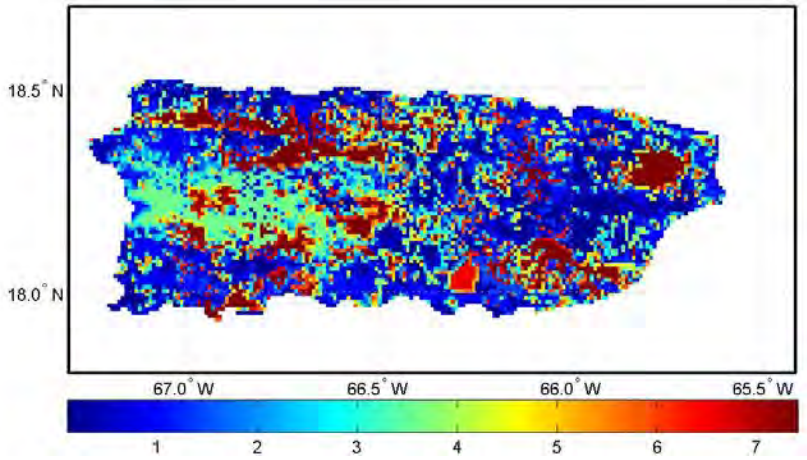


(Obtained from RAMS Surface Characteristics Dataset, http://bridge.atmet.org/users/data.php)

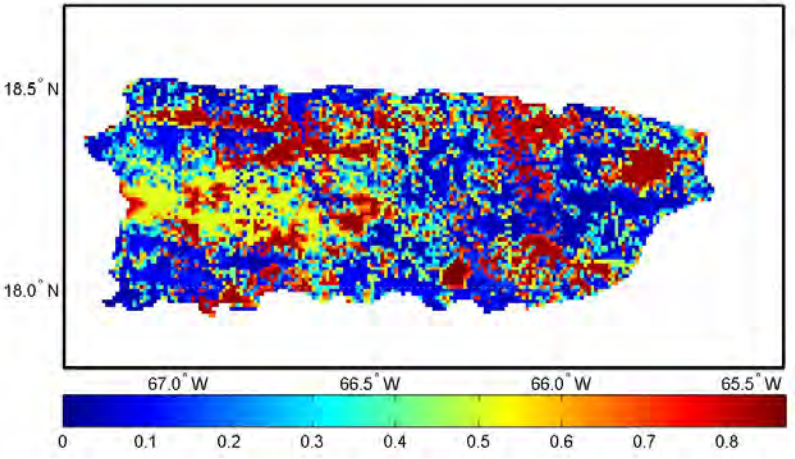
Land Cover



Zero Plane Displacement

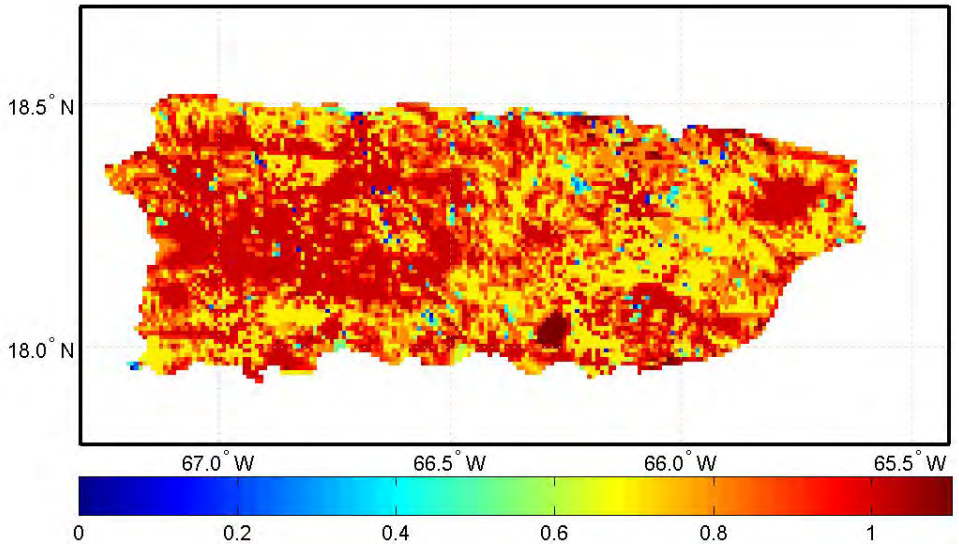


Surface Roughness

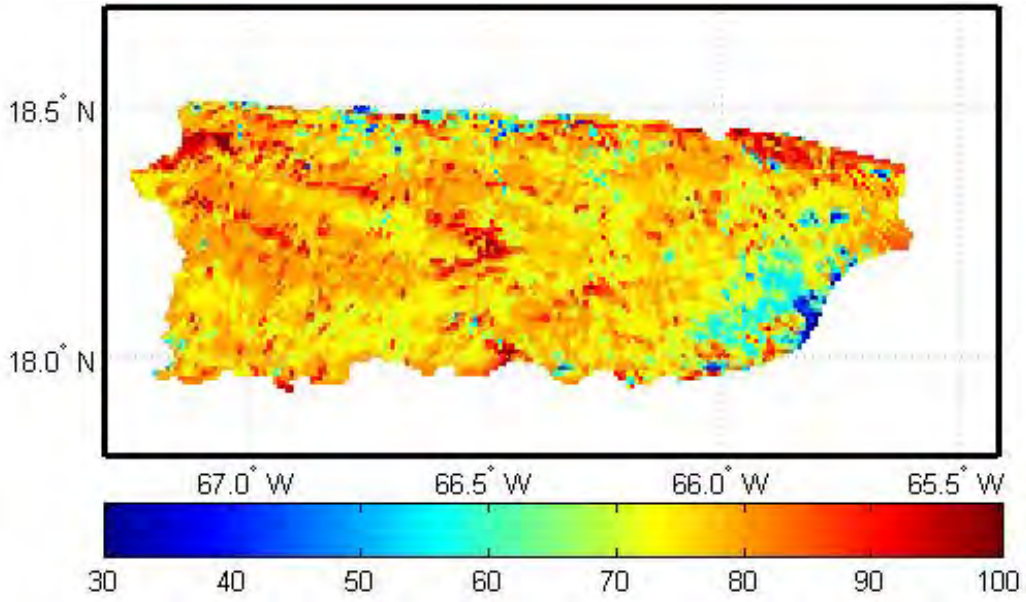


(Root depth obtained from RAMS Surface Characteristics Dataset, http://bridge.atmet.org/users/data.php)

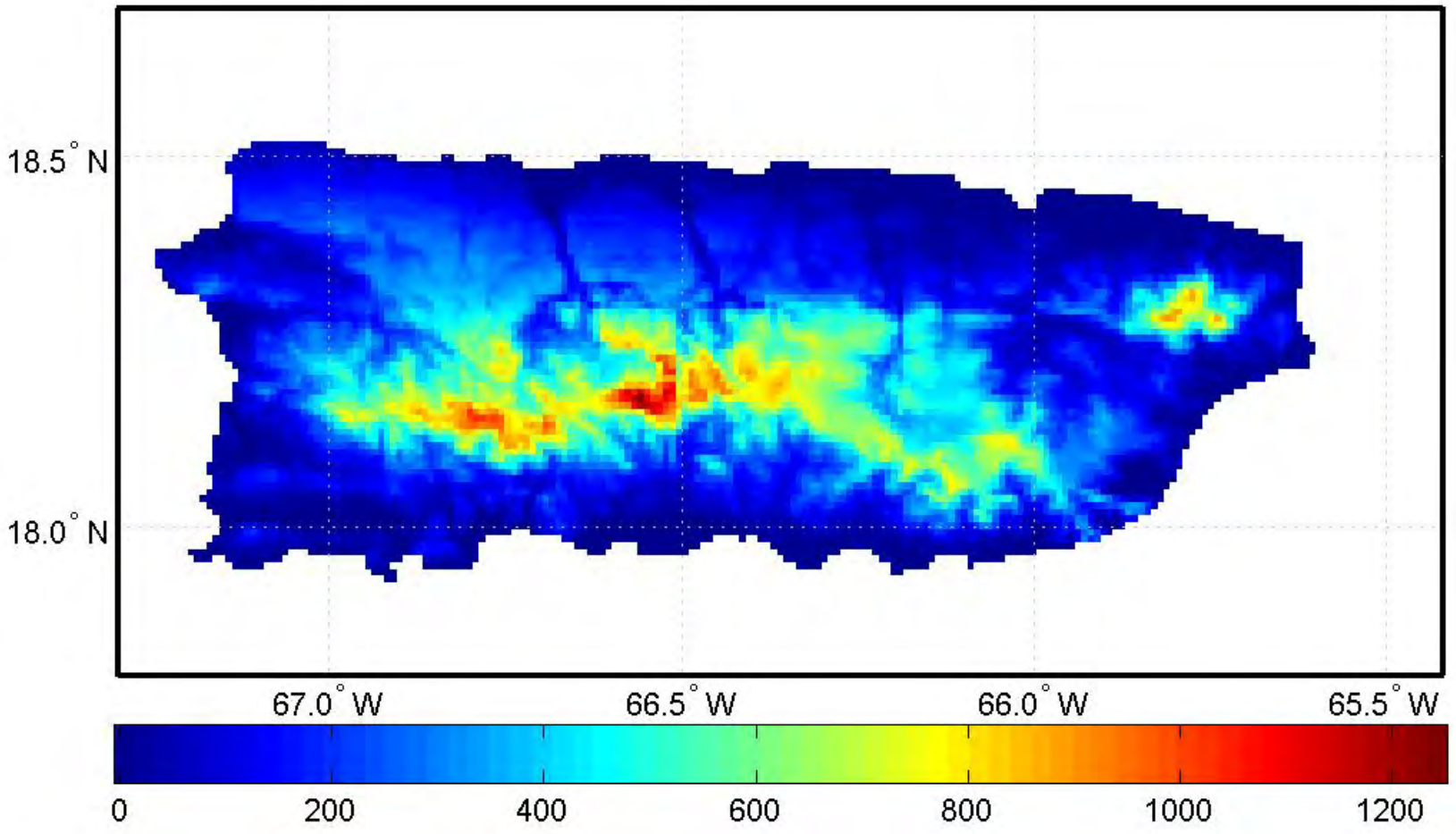
Root depth



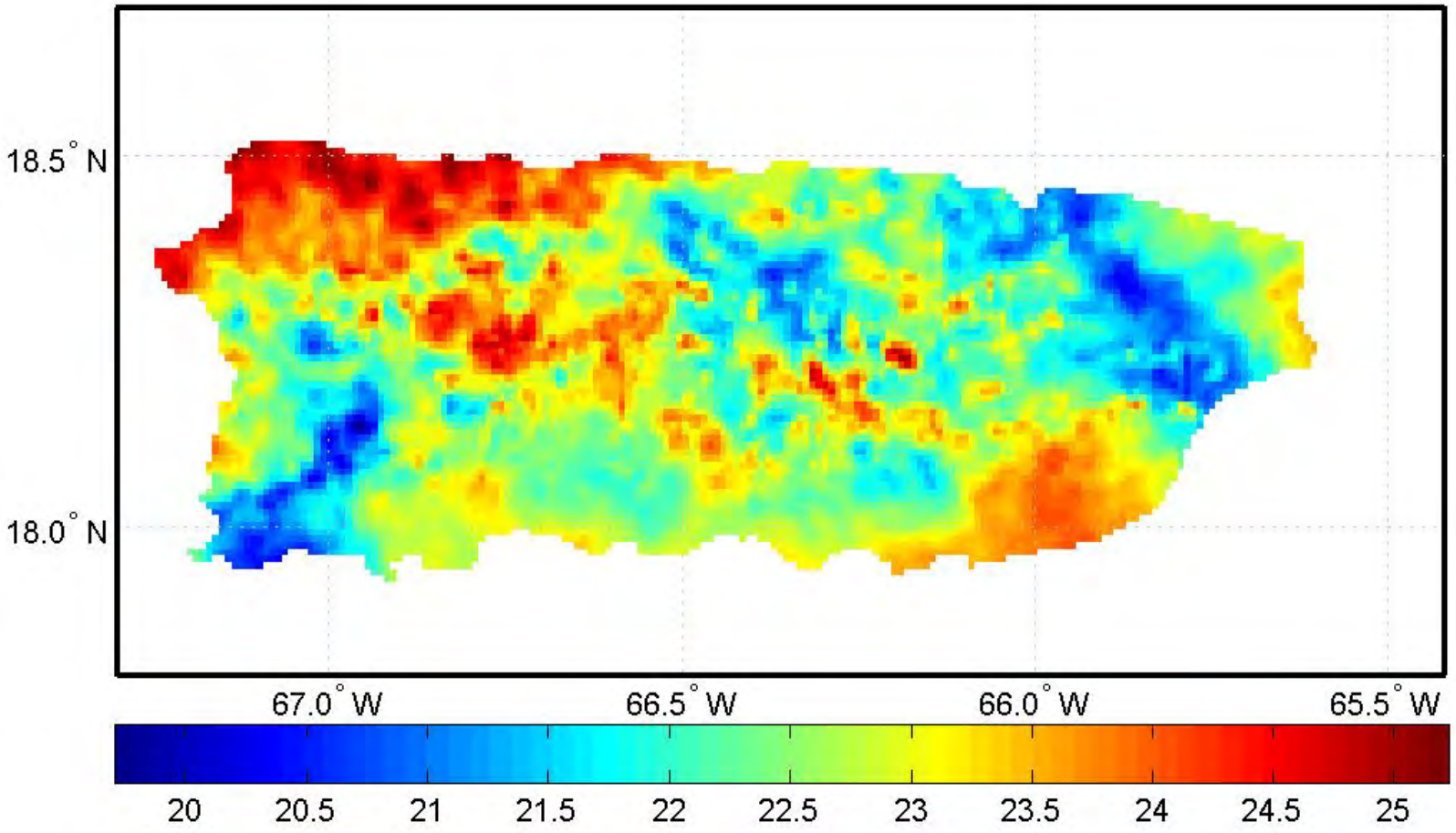
CN number



Puerto Rico Surface Elevation (m)

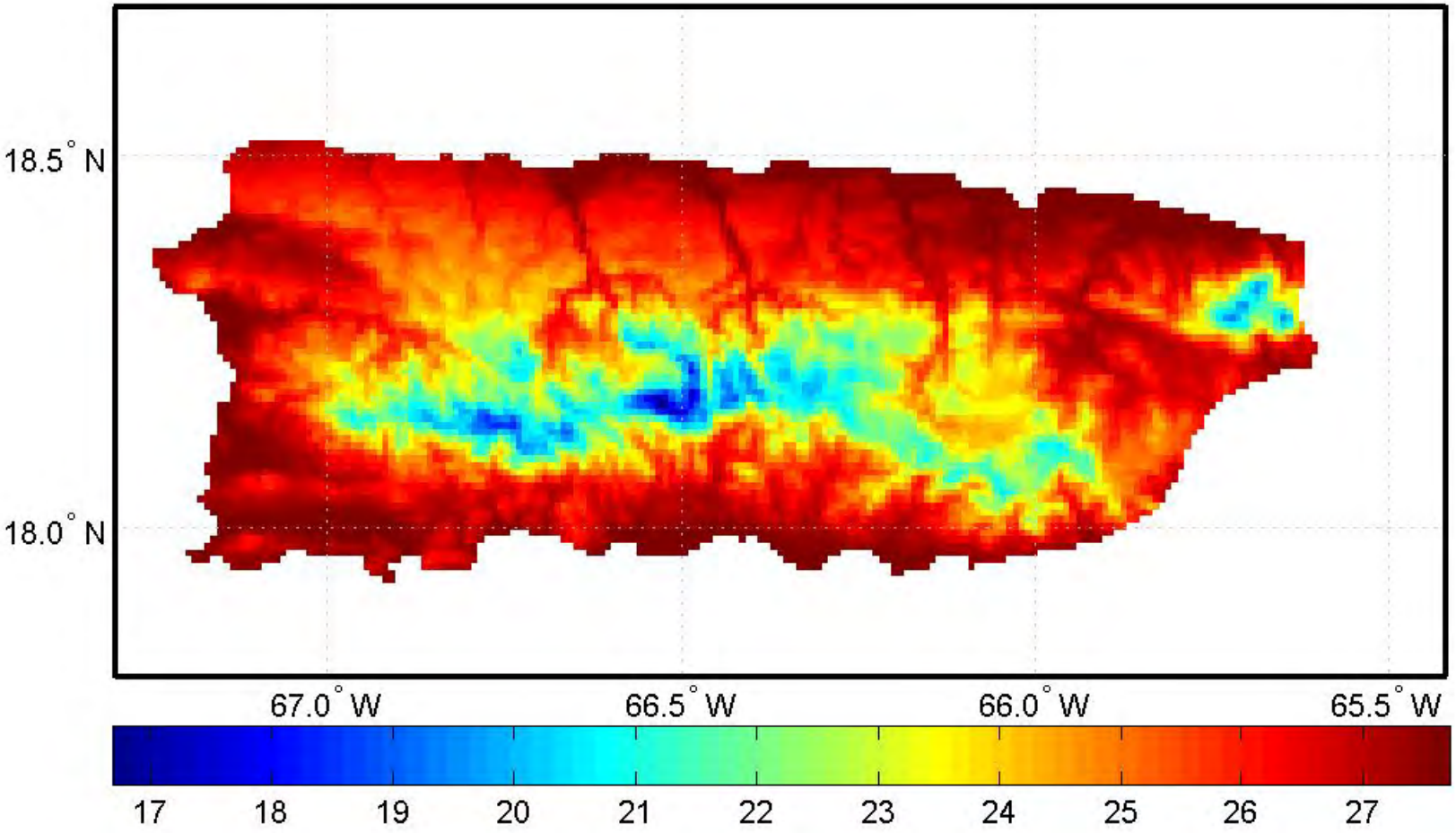


GOES-13 Integrated Daily Solar Radiation ($MJ/m^2/day$) for Puerto Rico on June 29th, 2010.

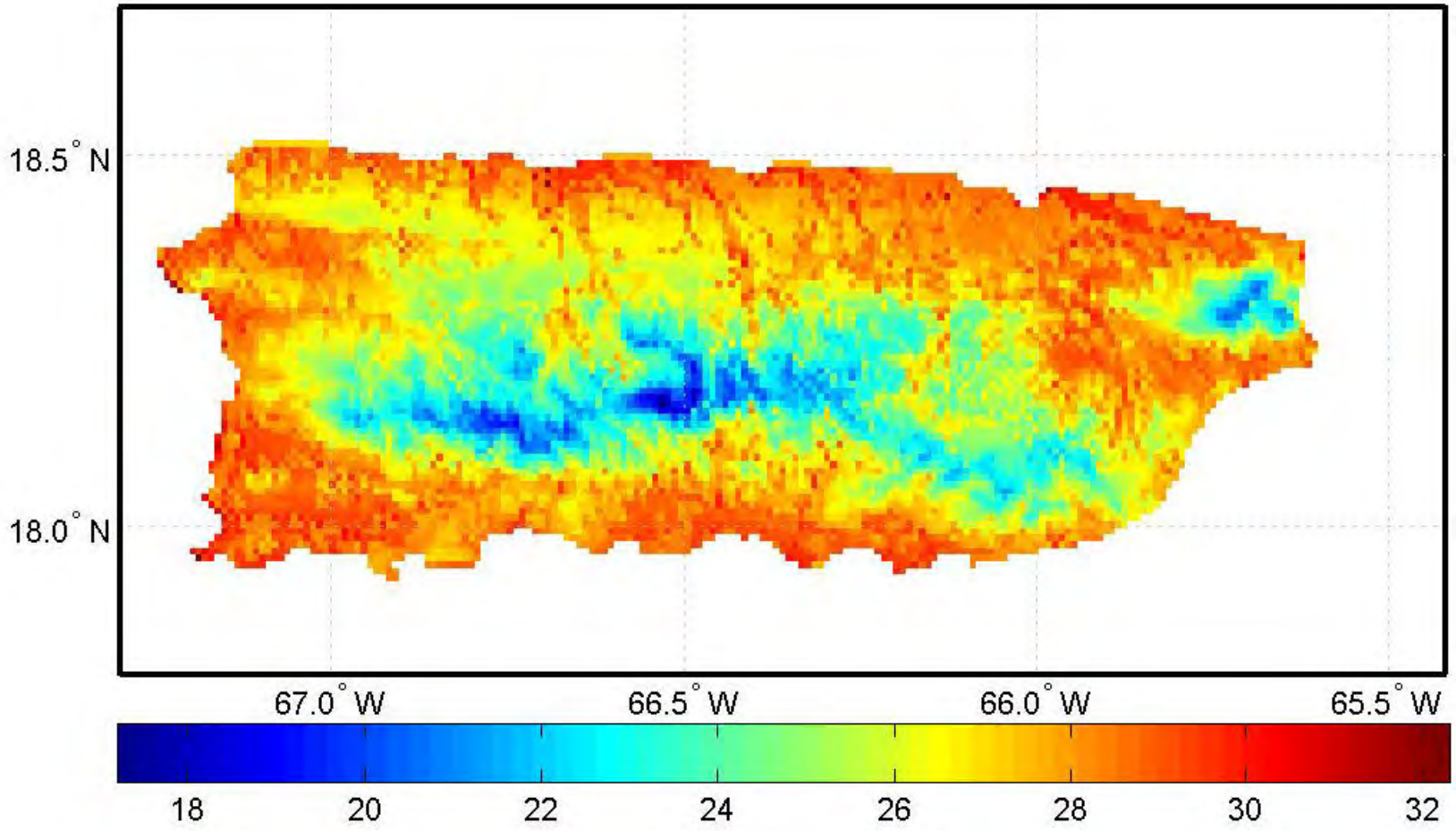


Estimated Average Air Temperature for PR on June 29th, 2010

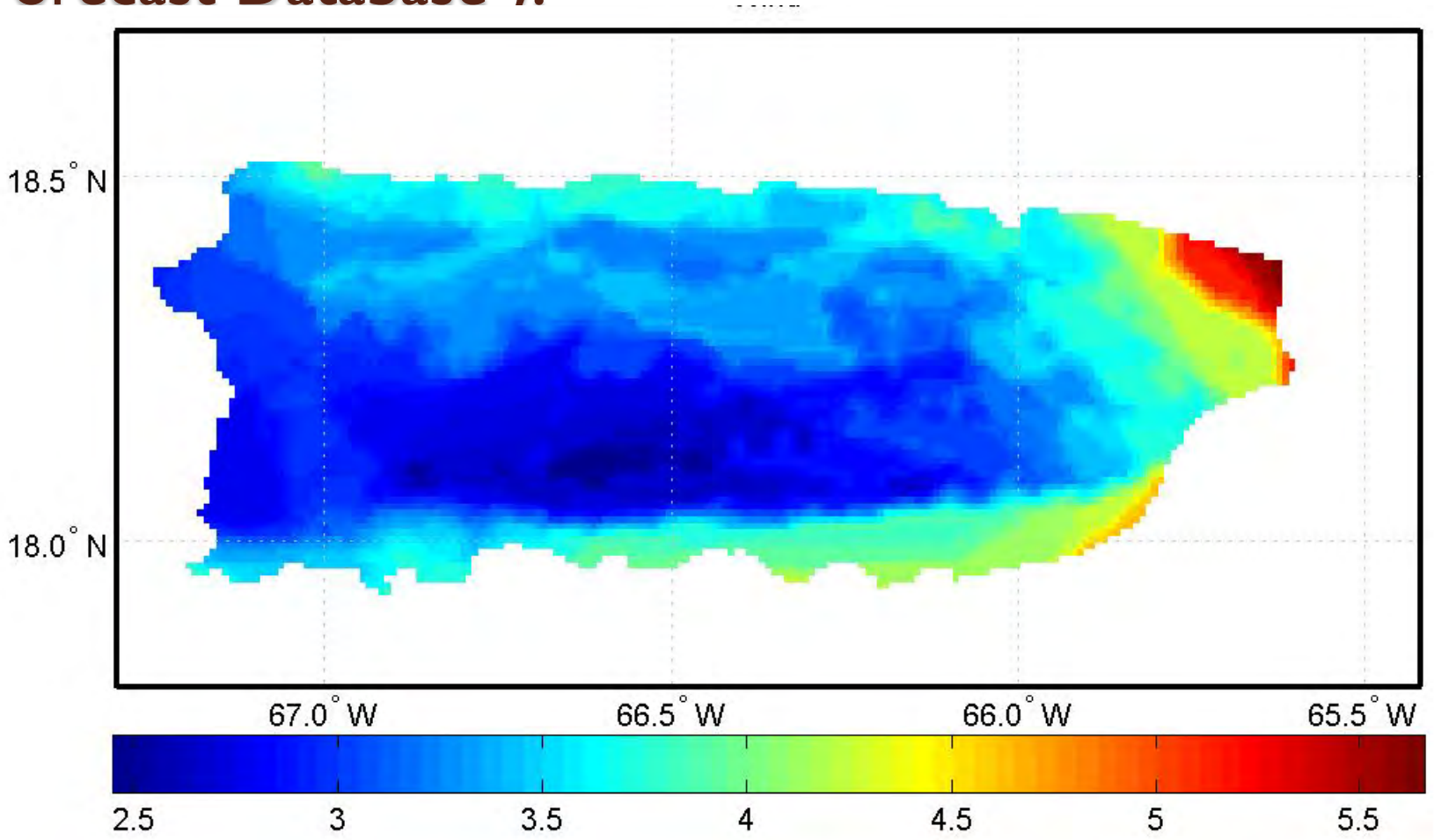
(Obtained using lapse rate approach of Goyal et al. (1988), adjusted with measured air temperatures)



Effective Surface Temperature for PR on June 29th, 2010.

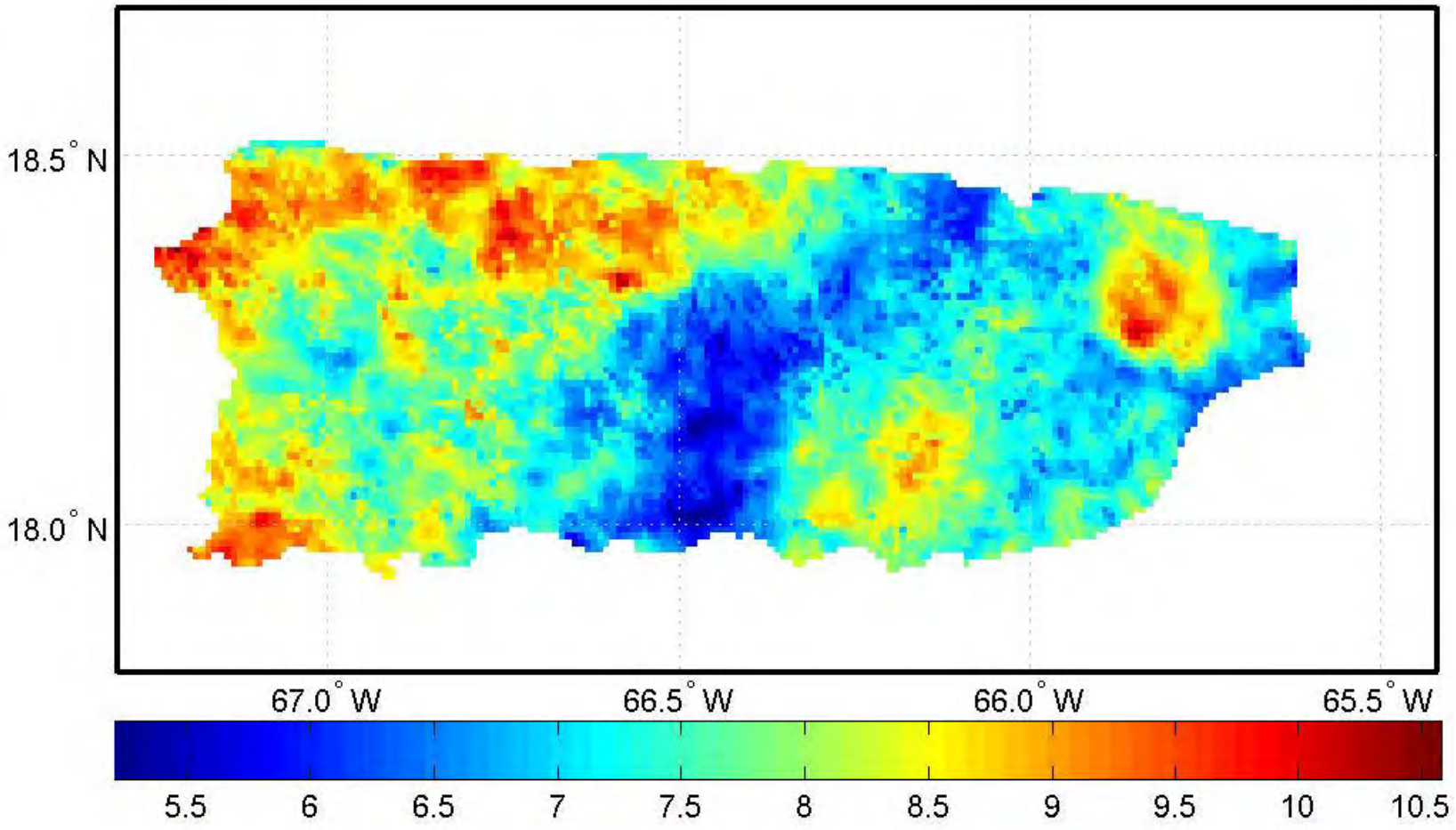


Wind Speed (m/s) for Puerto Rico on June 29th, 2010 (National Weather Service's National Digital Forecast Database).

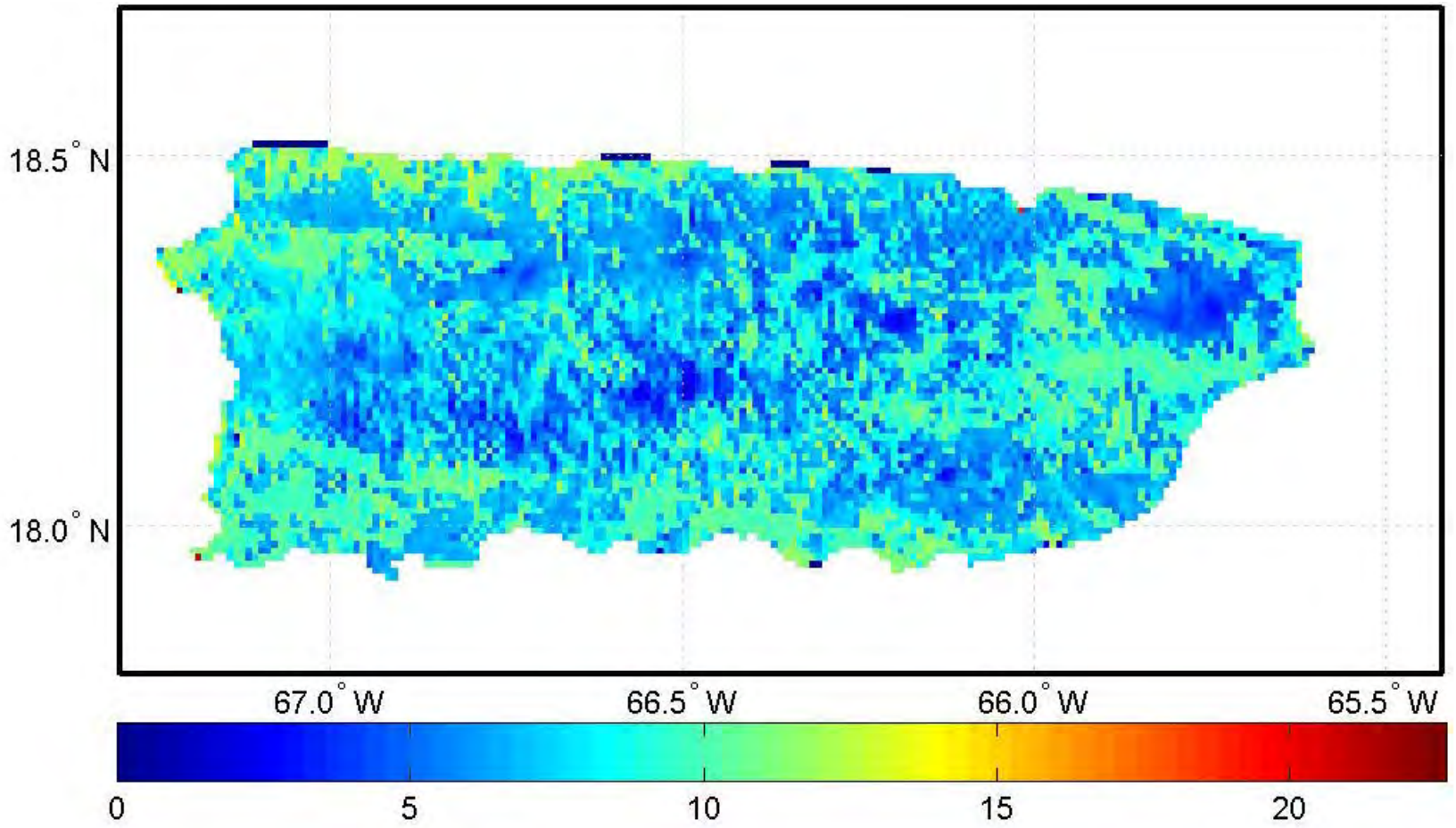


NET Radiation (MJ/m^2/day) for Puerto Rico on June 29th, 2010

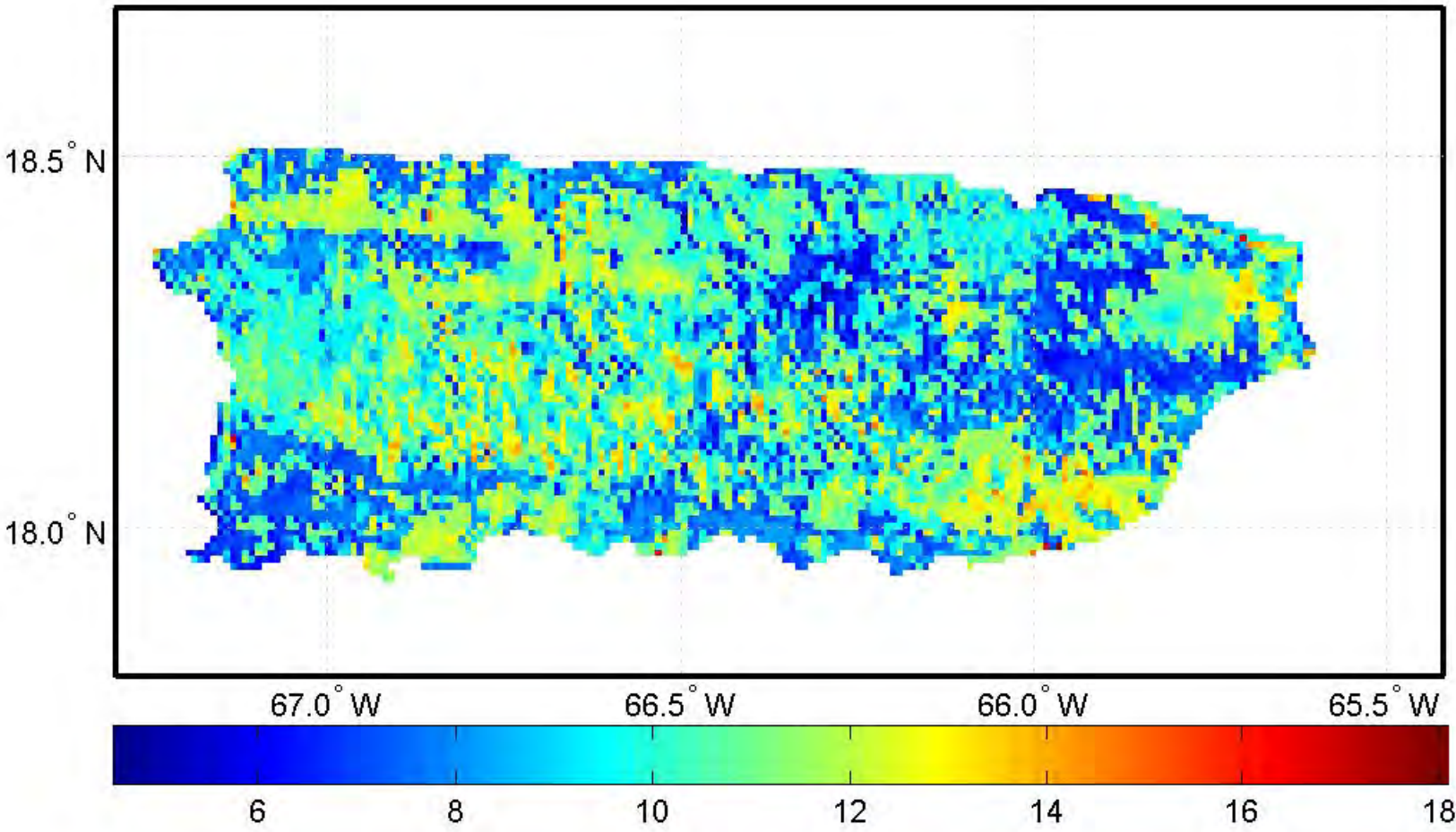
(Eestimated from solar radiation using method presented by Allen et al., 1998)



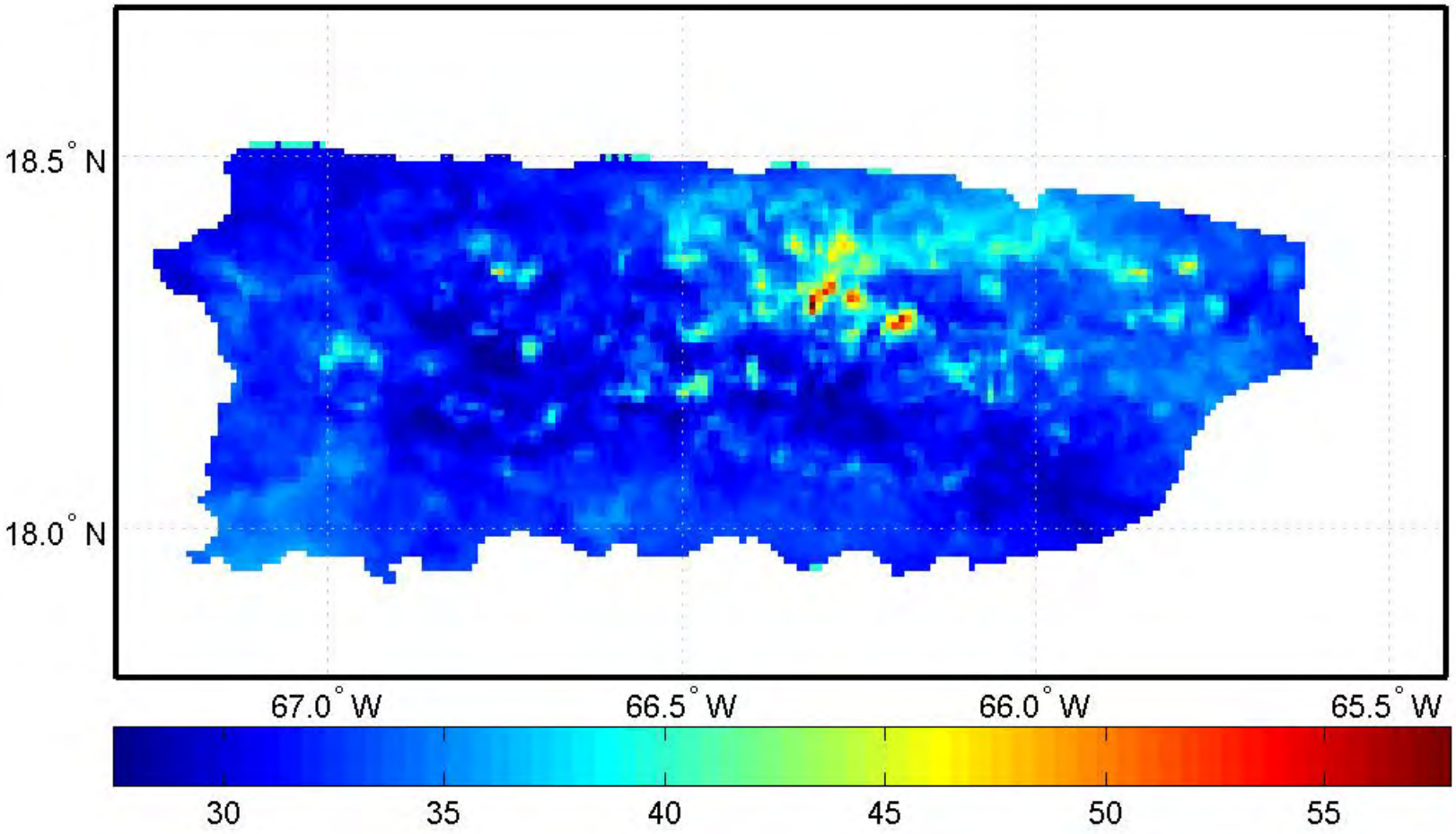
Latent Heat Flux (MJ/m^2/day) for Puerto Rico on June 29th, 2010



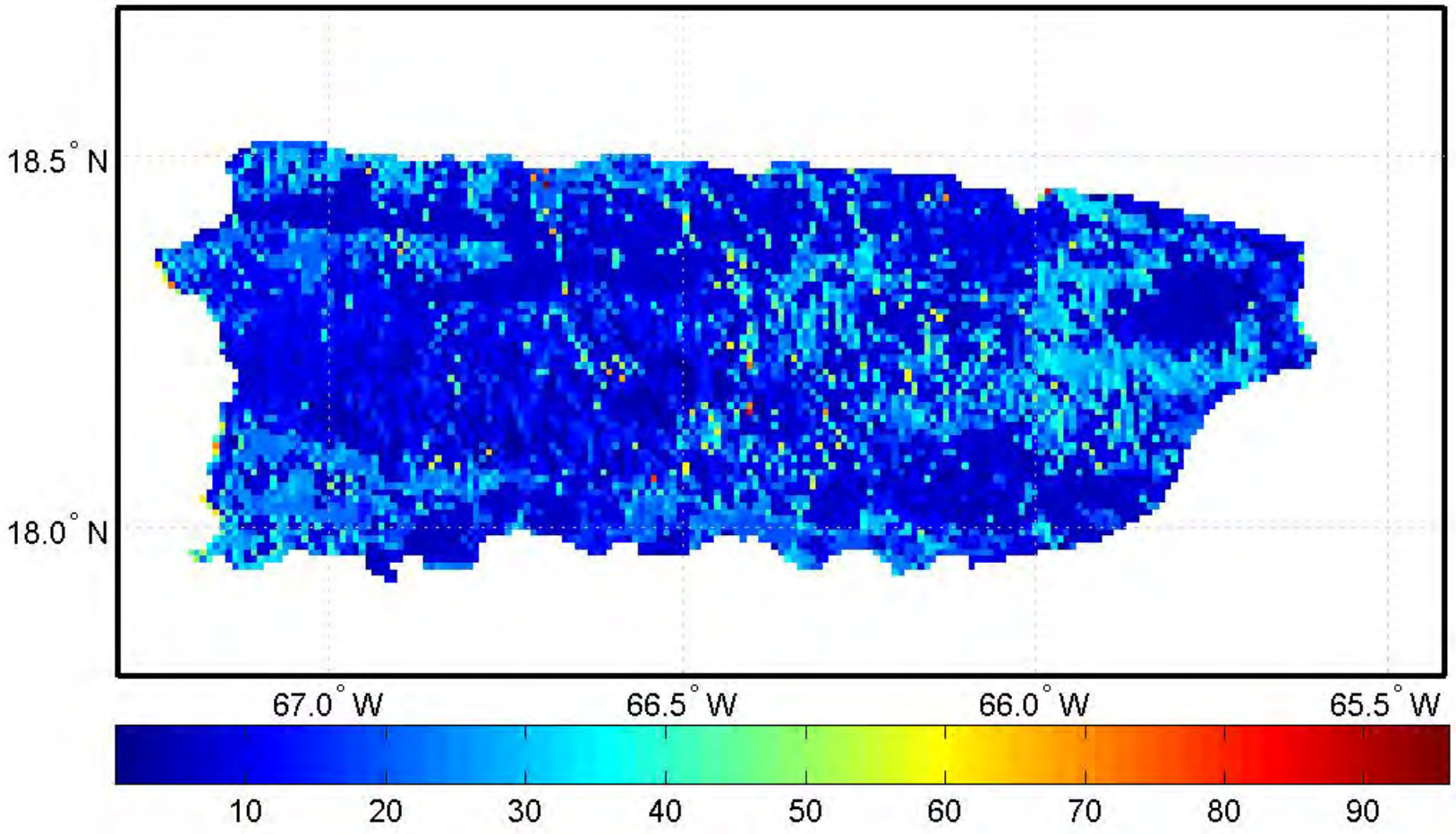
Sensible Heat Flux (MJ/m^2/day) for Puerto Rico on June 29th, 2010



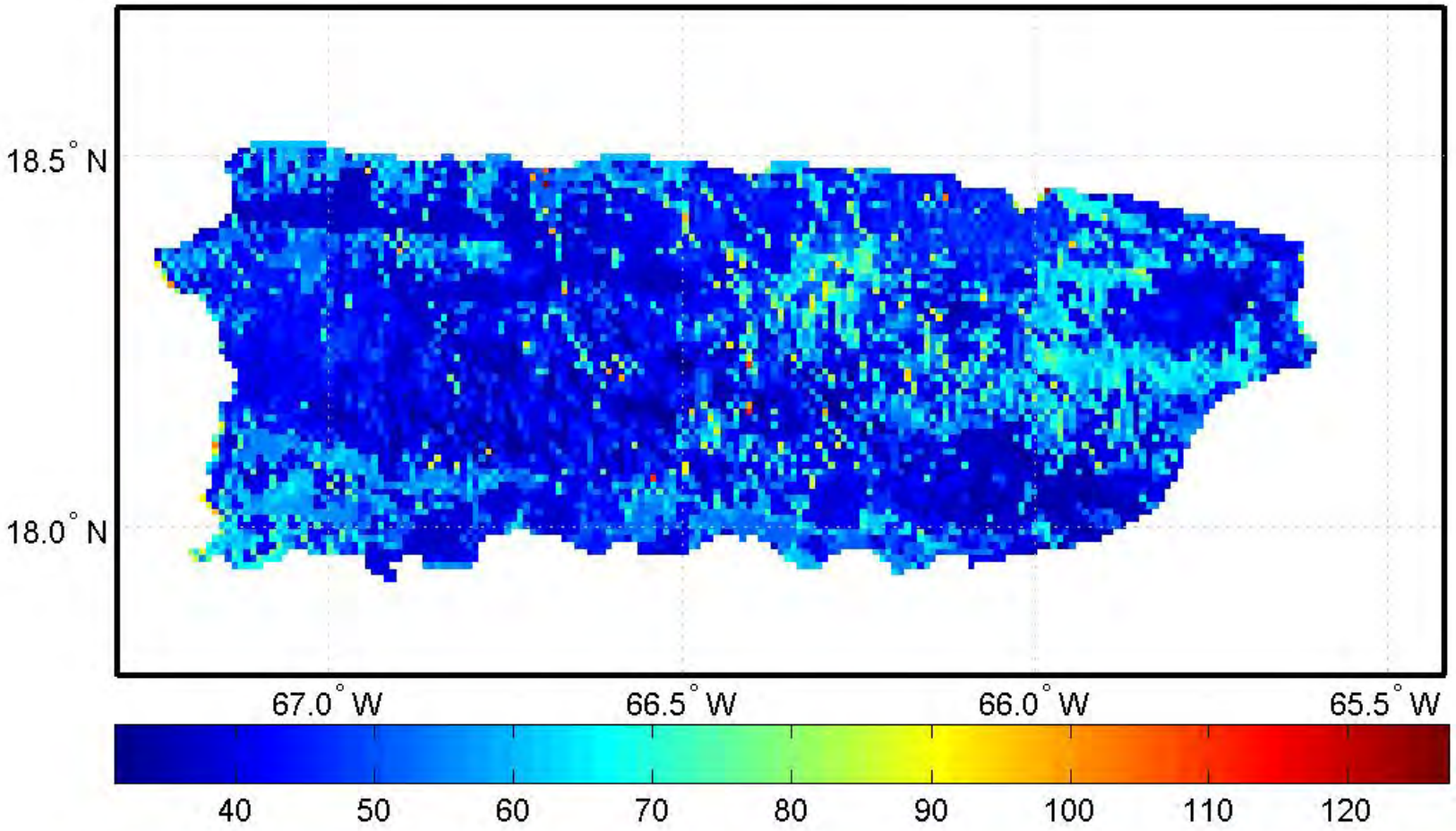
Bulk Surface Resistance (s/m) for Puerto Rico on June 29th, 2010



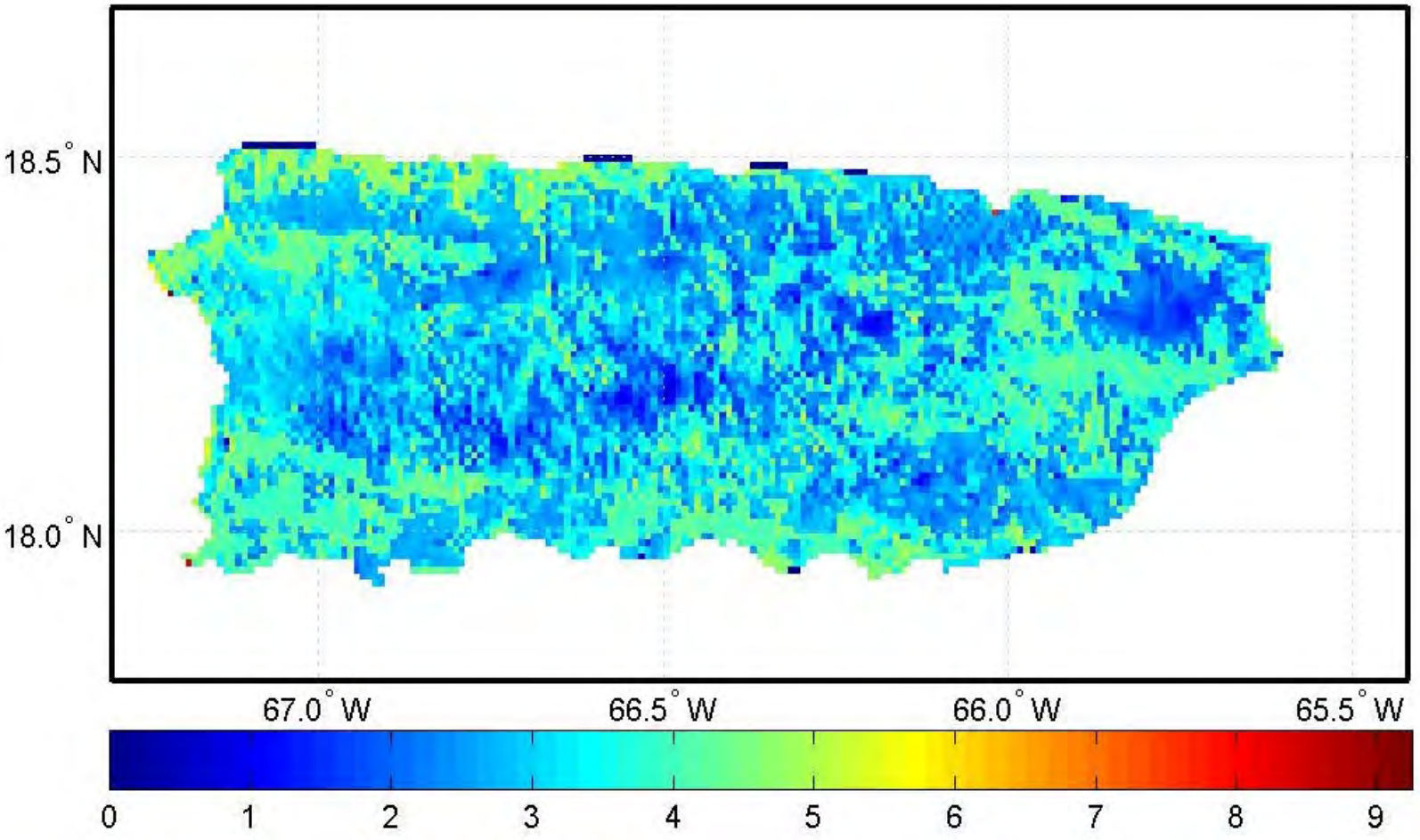
Aerodynamic Resistance (s/m) for Puerto Rico on June 29th, 2010



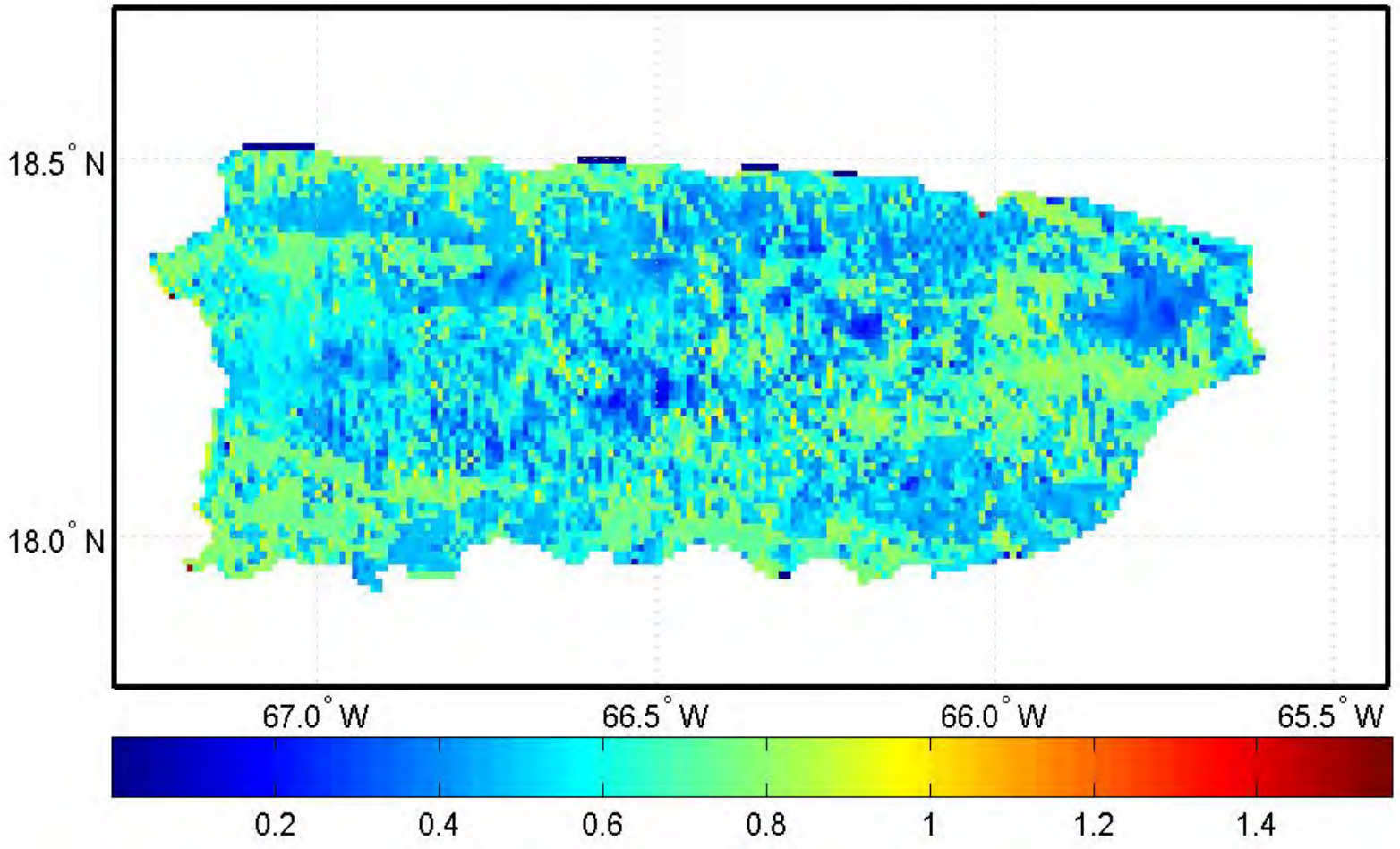
Bulk Surface Resistance + Aerodynamic Resistance (s/m) for Puerto Rico on June 29, 2010



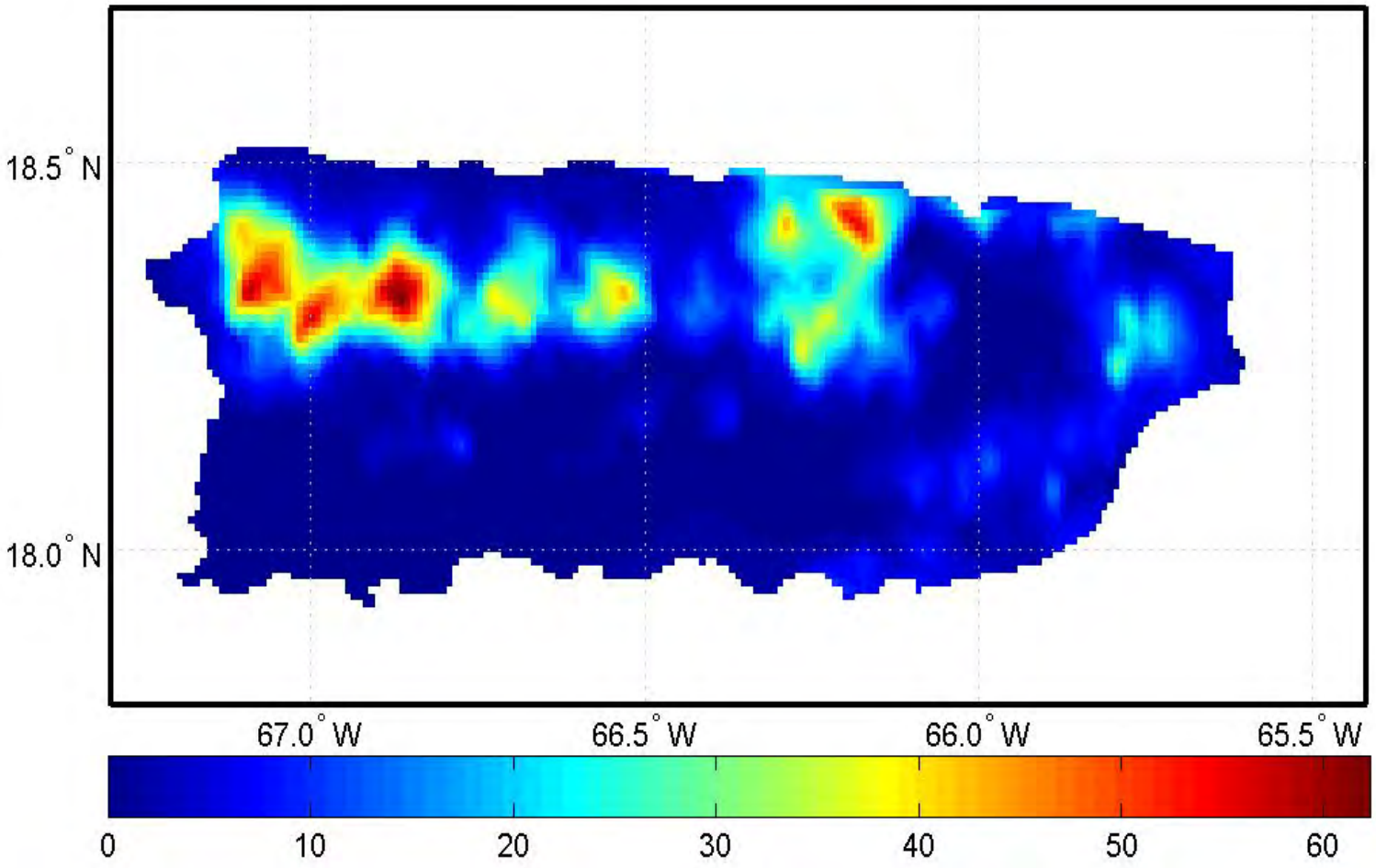
Estimated Actual Evapotranspiration (ET_a) for Puerto Rico on June 29th, 2010.



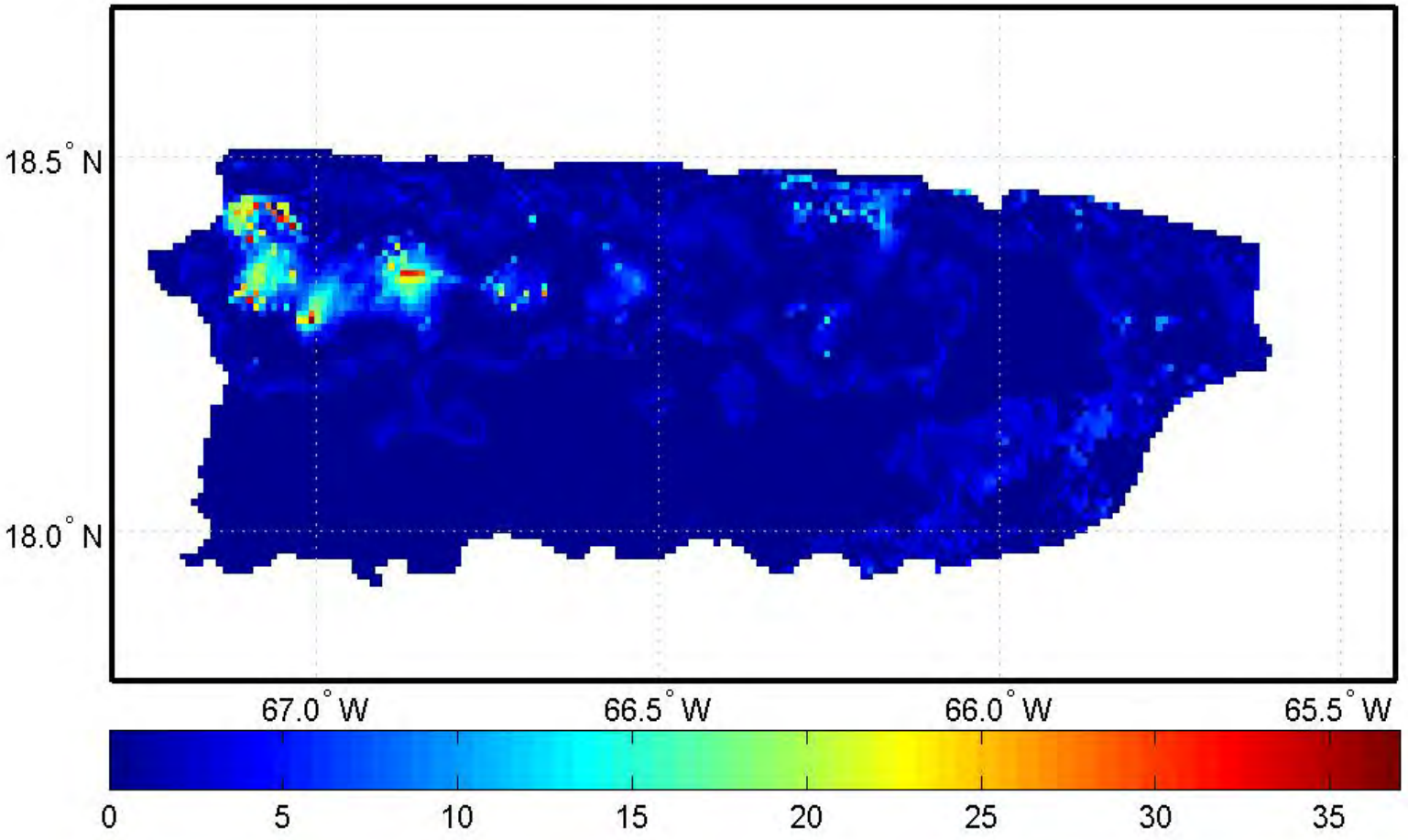
Estimate "crop" coefficient (K_c) over Puerto Rico on June 29, 2010.



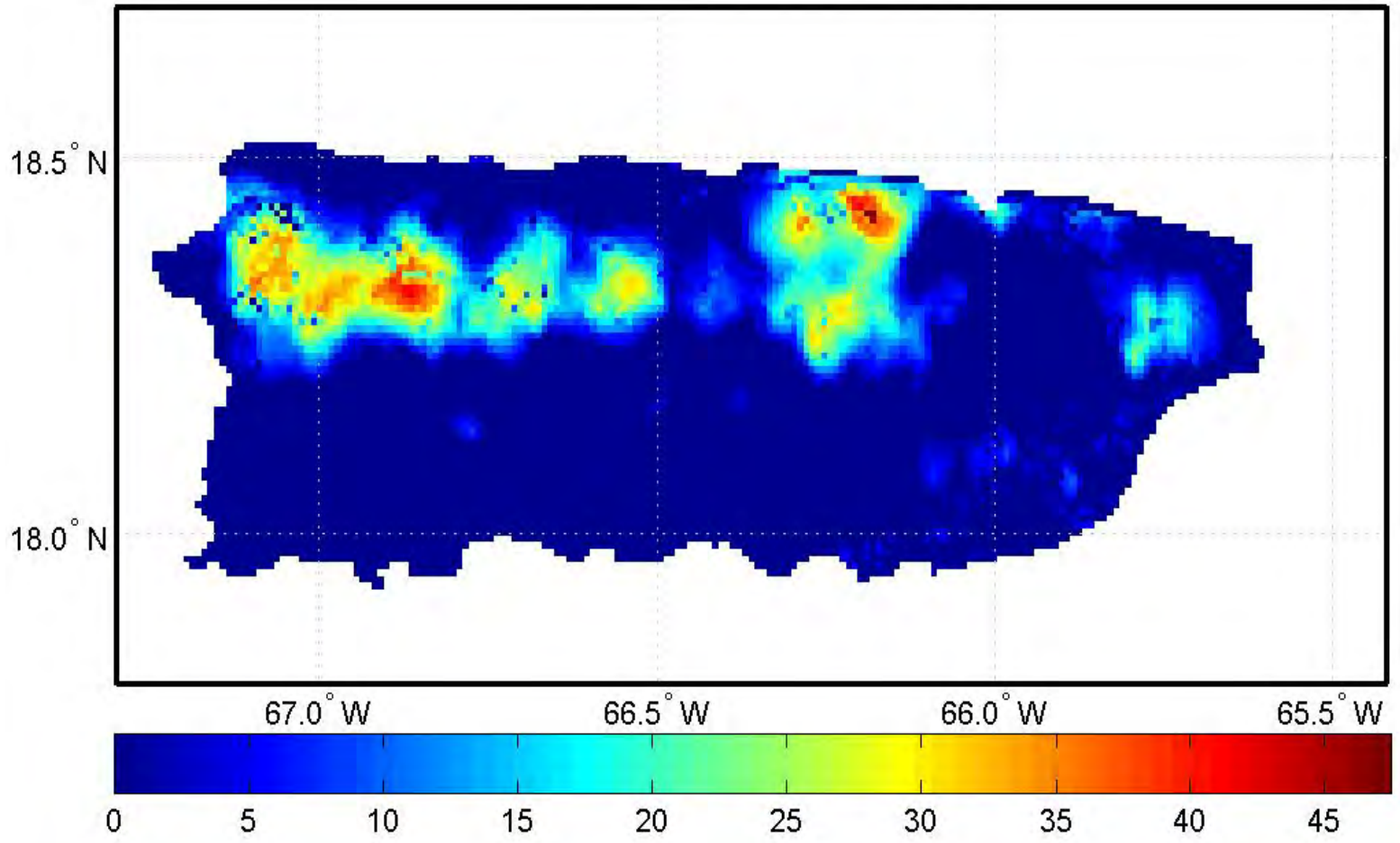
Rainfall over Puerto Rico on June 29, 2010 (NOAA's Advance Hydrologic Prediction Services).



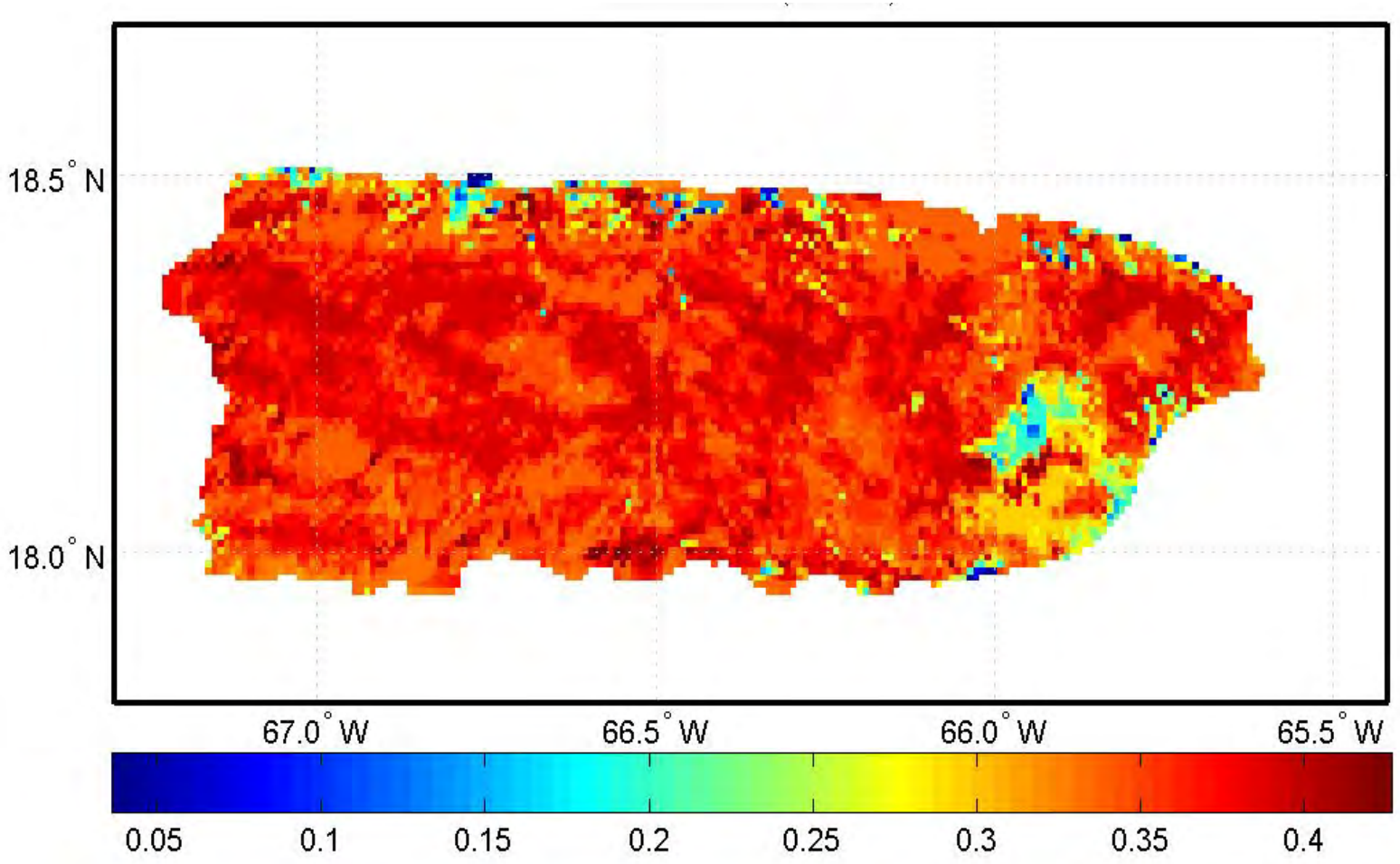
Estimated surface runoff in Puerto Rico on June 29, 2010.



Estimated deep percolation on June 29, 2010.



Estimated soil moisture in Puerto Rico on June 29, 2010.



Summary and Conclusions

- We describe a method for estimating **reference** evapotranspiration in Puerto Rico, Haiti and the Dominican Republic.
- Methods for estimating the **actual** evapotranspiration and the water and energy budgets over Puerto Rico were described.
- Estimates of **reference** evapotranspiration for June 29, 2010, were provided for Puerto Rico, Haiti and the Dominican Republic,
- Estimated **actual** evapotranspiration, surface runoff, deep percolation and soil moisture content for Puerto Rico for the same day were presented. Components of the energy balance were also presented.

Future Work

- Complete the actual ET and water balance algorithm for DR and Haiti
- Automate the calculation process, which will publish the daily results on a website each day.
- Provide archived tabular and graphical results, and statistics of these data (e.g., wet season aquifer recharge)

Acknowledgements

- Financial Support:
  - USDA-Hatch (H-402)
  - NOAA-CREST (NA17AE1625)
  - NSF-CASA (NSF 0313747)