Modeling and Application of Soil Temperature in the Mojave and Lower Colorado Deserts of California.

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Backround

- Soil temperature work in the Mojave Desert began with hyperthermic-thermic "line" study conducted by National Soil Survey Center in 2000 (Mount and Paetzold, 2002). Sites were originally placed around the 3000' elevation mark in Joshua Tree National Park, Anza Borrego State Park and other BLM-managed areas of the Mojave Desert (22 sites).
- As survey work expanded in the Mojave in early 2000's, 20 sites were added for local study.
- With this accumulated data, we developed models of mean annual soil temperature (MAST), based primarily on elevation and vegetative communities, in order to distinguish soil temperature regimes in the field.
- Soil Temperature is correlated with broad trends in desert vegetation communities, which allows us to be specific in our soil series information so that we classify soils as cool thermic, warm thermic, (e.g. 15-19, and 19 to 22 degrees C), rather than entire range of thermic or hyperthermic.

Methods

Study Area

- Our Major Land Resource Area (MLRA) is the Mojave and Lower Colorado Deserts of California (i.e. 30 and 31 respectively). Climatically, the Mojave is characterized by it's warm temperatures, higher portion of winter precipitation (44%), and cold winters which commonly produce freezing temperatures. By contrast, the Lower Colorado Desert (a subset of the Sonoran) is hotter than the Mojave, has a greater frequency of summer precipitation dominated by subtropical thunderstorms, and rarely has freezing temperatures (Laity, 2008).

Data collection:

- Presently we have 50 temperature monitoring sites spread throughout Mojave and Lower Colorado Deserts, which are collected annually.
- Currently the primary data loggers used are different varieties of HOBOs, including 4-channels.

Models:

- Initial generalized climate concepts (2003, by Haydu-Houdeshell, MLRA Project Leader)
  - Constructed table specifying generalized climate concepts, interpreted from MAST data. (Table 1., Table 2., Figure 1a.)
- Spatialized generalized climate concepts (4/2009, by Paul Rindfleisch, Soil Scientist)
  - Constructed according to the established generalized climate concepts, by the intersection of elevation and slope aspect.
  - Spatial extent of the model was clipped to the boundary of Joshua Tree National Park (JTNP) (approximately 792,000 acres).
  - Used to help determine temperature regimes for inaccessible areas of JTNP.
- Regression model 1st iteration (11/2009, David Howell, State GIS Specialist)
  - Constructed multiple linear regression model with 35 sites, and used 7 sites for validation (Figure 1b).
    - $MAST^2$ = 5.73 + (-0.90 * Soil Adjusted Vegetation Index) + (-0.0009 * Elevation) + (0.011 * Slope) + (0.036 * Annual Solar Radiation) + (-0.103 * Summer Solar Radition)
  - Spatial extent of the model was designed to cover the area designated as the Mojave Operational Initiative (approximately 9,660,000 acres).
- Regression model 2nd iteration (12/2011, Stephen Roecker, Soil Scientist)
  - Constructed multiple linear regression model with 49 sites, and used 10-fold cross validation (Figure 1c , 1d, and 2).
    - MAST = 40.23 + (-0.009 * Elevation) + (-0.23 Coefficient of Variation (CV) in Solar Radiation) + (-0.02 * Tasseled Cap 1 (e.g. albedo))
  - Spatial extent of the model was clipped to the watersheds that intersect the Mojave and Lower Colorado Deserts (e.g. MLRA 30 and 31) (approximately 37,800,000 acres).

Figure 2. Overview of the MAST model of the Mojave and Lower Colorado Desert with HOBO logger locations.

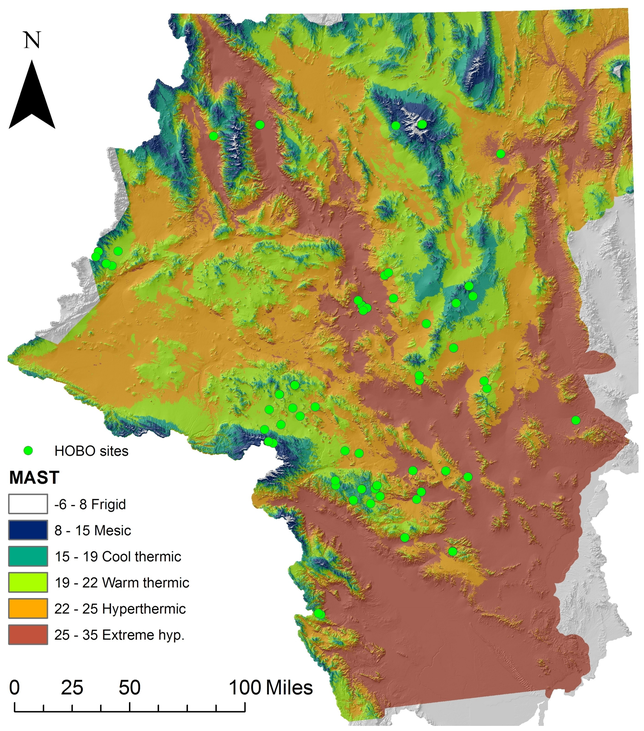
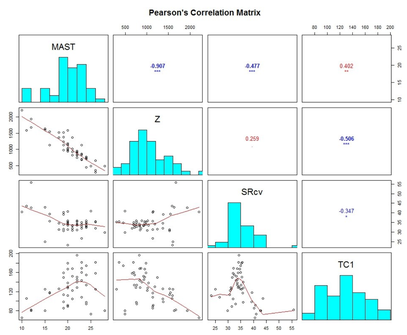


Figure 3. Scatterplot of MAST, elevation (Z), coefficient of variation in solar radiation (SRcv), and tasseled cap 1



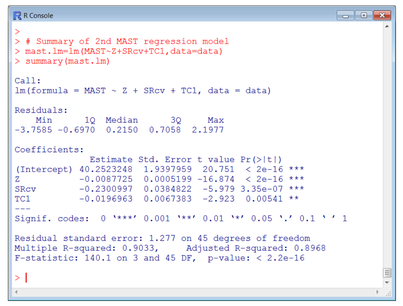


Table 3. Statistical summary of 2nd MAST multiple linear regression model.

Results

- Exploratory analysis of MAST, and DEM and RSI derivatives shows elevation, solar radiation, and albedo to be correlated (Figure 3).
- No formal statistical accuracy assessment as of yet has been made of the initial or updated generalized climatic concepts (Table 1 and 2, and Figure 1a.).
- The 1st regression model has an R^2 of 0.83, with the validation dataset (7 sites).
- The 2nd regression model has a resubstituted R^2 of 0.90 (Table 3)., and a 10-fold cross -validated R^2 of 0.75.

Discussion

- Because MAST is primarily driven by elevation in California's warm deserts, our generalized climatic concepts explain their relationship in a straightforward manner.
- The 1st regression model captured the overall MAST trend. However, it appears to overestimate MAST on steep south slopes. Also, further examination of the regression model's diagnostics reveal it to be over leveraged with respect to solar radiation, and therefore unstable.
- The 2nd regression model has a more stable fit than the 1st, and is more consistent with our vegetation concepts on steep south slopes. The prediction confidence interval shows the highest standard error (i.e. uncertainty) is associated with steep slopes (>50% percent), extremely dark or light surfaces, and extreme lows and highs in elevation (e.g. Death Valley and San Bernardino Mountains). These instances all correspond with areas that are under sampled in the 2009 MAST dataset. Therefore we have placed new 10 samples in these under sampled areas within Mojave National Preserve, in an effort to further improve this model.

Table 1. Initial generalized climate concepts for the Mojave Desert.

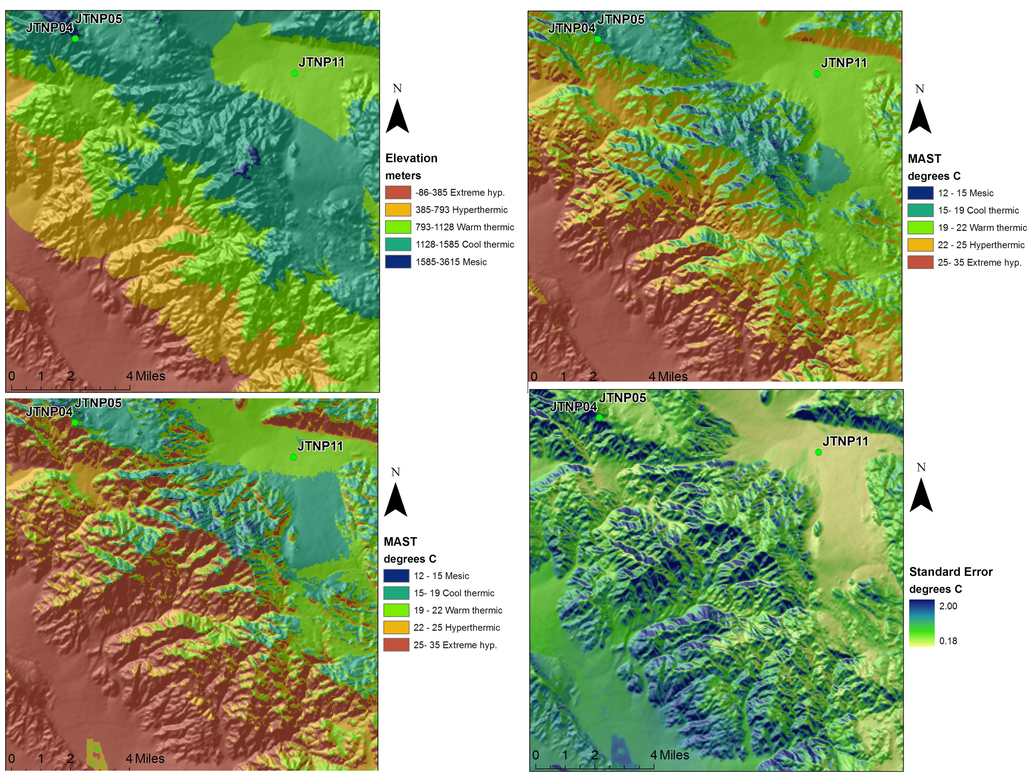
Temperature Regime	Elevation (feet)	Elevation (meters)	MAST (°C)	MAST (°F)	MAAT (°C)	MAAT (°F)	Precipitation (inches)	Precipitation (mm)	Frost-free days
MESIC	>5200	>1585	12-15	53-59	10-13	50-55	6-8	150-205	160-200
THERMIC									
South Aspect	>2600	>792	15-18	59-64	13-16	55-61	4-7	100-175	210-270
cool	3700-5200	1128-1585	15-19	59-66	13-17	55-63	4-7	100-175	210-270
hot	2600-3700	792-1128	19-22	66-72	17-20	63-68	4-7	100-175	280-320
HYPERTHERMIC	<2600	<792	22-25	72-77	20-23	68-73	2-4	50-100	300-360
North Aspect	<2400	<732	22-24	72-75	20-22	68-72	2-4	50-100	300-360
South Aspect	<3700	<1128	22-24	72-75	20-22	68-72	2-4	50-100	300-360

Table 2. Updated generalized climate concepts for the Mojave Desert.

Temperature Regime	Elevation (feet)	Elevation (meters)	MAST (°C)	MAST RV	MAST (°F)	MAAT (°C)	MAAT RV	MAAT (°F)	Precipitation (in)	Precipitation (mm)	Precipitation RV	Frost-free days (days)	Frost-free days RV
MESIC	>5200	>1585	12-15	13.5	53-59	10-13	11.5/52.5	52-57	6-8	150-205	17	160-200	180
THERMIC	2600-5200	793-1585	15-22	18.5	59-72	13-20	16.5/61.5	55.5-68	4-7	100-175	13 7.5	210-320	265
cool	3700-5200	1128-1585	15-19	17	59-66	13-17	15/59	55.5-61.5	4-7	100-175	13 7.5	210-270	240
warm	2600-3700	793-1128	19-22	21.5	66-72	16.5-20	18/64.5	61.5-68	4-7	100-175	13 7.5	270-320	295
HYPERTHERMIC	<2600	<793	22-25	23.5	72-77	20-23	21.5/71	68-73.5	2-4	50-100	75	300-365	333
North Aspect	<2600	<793	22-24	23	72-75	20-22	21/70	68-72	2-4	50-100	75	300-365	333
South Aspect	<3700	<1128	22-24	23	72-75	20-22	21/70	68-72	2-4	50-100	75	300-365	333
MLRA 31			25-28	26.5	77-82	23-27	25/77	73.5-	2-4	50-100	75	365-365	365

Note: These are general guidelines. Sometimes the cool thermic/warm thermic line is fuzzy. We have some map units where the veg is purely CORA-JUCA7 (a cool thermic indicator ecological concept) and the map unit is 4000 to 5000 feet. We have others where the warm thermic veg of CORA-LATR goes up to 4000 feet. Our 10 years of data indicate our break is about 3700 to 3900 feet.

Figure 1. Comparsion of MAST models. Snapshot of Little San Bernardino Mountains within Joshua National Park. a) (Upper left) Generalized climatic concepts based on elevation thresholds. b) (Lower left) 1st regression model. c) 2nd regression model. d) standard error 2nd regression model.



Summary

- We created a digital soil map of MAST for the Mojave and Lower Colorado Deserts.
- Soil temperature regimes are useful breaks for segmenting broad vegetative communities. However, in the field, boundaries between temperature regimes are diffuse, and cut across landforms. Therefore in the office we pre-delineate the boundaries between soil temperature regimes according to elevation ranges, confirm with vegetative communities in the field when feasible, and defer to our MAST models elsewhere.
- Recent research by Bai et al. (2010) determined an elevation threshold of 1051-meters (3448-feet) to distinguish between hyperthermic and thermic soils in the Mojave Desert. They also found no significant relationship between MAST and aspect. In contrast the results to our 2nd regression model suggest the threshold between hyperthermic and thermic soils should on average be 891-meters (2923-feet). In addition, we also found the effect of solar radiation and albedo on MAST to be significant.

References

- Bai, Y., T.A. Scott, W. Chen, R.C. Graham, L. Wu, A.C. Chang, and L.J. Lund, 2010. Soil Temperature Regimes in the Mojave Desert. Soil Science, 175(8):398-404.
- Laity, J., 2008. Deserts and Desert Environments. Wiley-Blackwell, West Sussex, UK.
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