i-Tree Tools for Mapping Extreme Heat Risk and Mitigation in New York State Disadvantaged Communities

Climate Justice Working Group

New York State Department of Environmental Conservation

Climate Leadership and Community Protection Act

October 4, 2023 on WebEx

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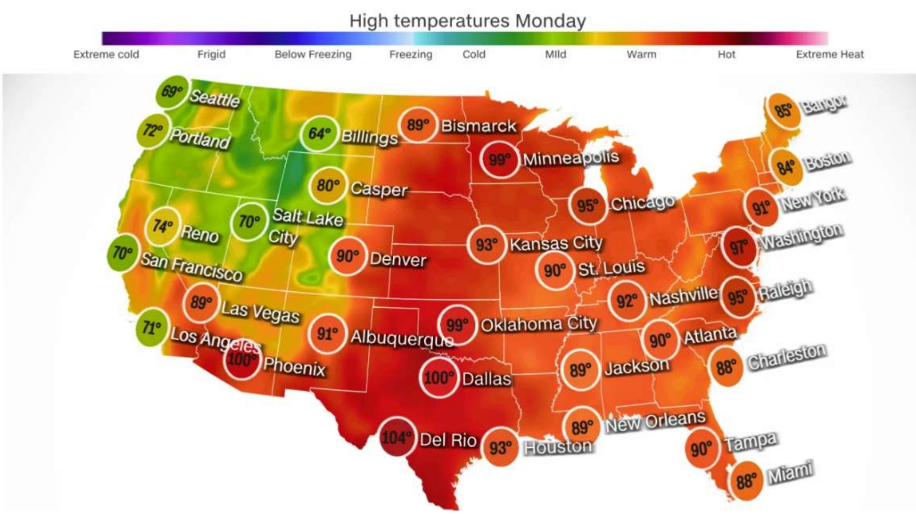
i-Tree is a Cooperative Initiative

Motivation: Reduce Extreme Heat Exposure & Vulnerability with Sustainable Urban Forests

Labor Day sizzle: Extreme heat spreads across two-thirds of US this weekend

By Mary Gilbert, CNN Meteorologist
Published 12:11 PM EDT, Fri September 1, 2023



https://www.cnn.com/2023/09/01/weather/labor-day-forecast-heat-rip-currents/index.html

September 6, 2023

As Heat Rises and Electric Bills Soar, Gov. Hochul Must Protect NYers By Passing NY HEAT Act

NY Governor Hochul must pass the NY HEAT Act in this year's budget to fight climate change and protect New York families

CONTACTS

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Marissa Solomon, marissa@pythiapublic.com

ALBANY, NY — After a hot, expensive, toxic, scorching summer, another dangerous, potentially record-breaking heat wave is blanketing New York this week. Liz Moran, New York Policy Advocate at Earthjustice, issued the following statement:

https://earthjustice.org/press/2023/as-heat-rises-and-electric-bills-soar-gov-hochul-must-protect-nyers-by-passing-ny-heat-act

i-Tree Tools for Nature-Based Solutions

User Support

- City Benefits Calculator — i-Tree Eco
- City Benefits Viewer — i-Tree Landscape
- City Benefits Summary — i-Tree Our Tree
- Site Benefits Summary — i-Tree My Tree
- Land Cover & Benefits Estimator — i-Tree Canopy
- Tree Species Selection — i-Tree Species

Research Suite HydroPlus

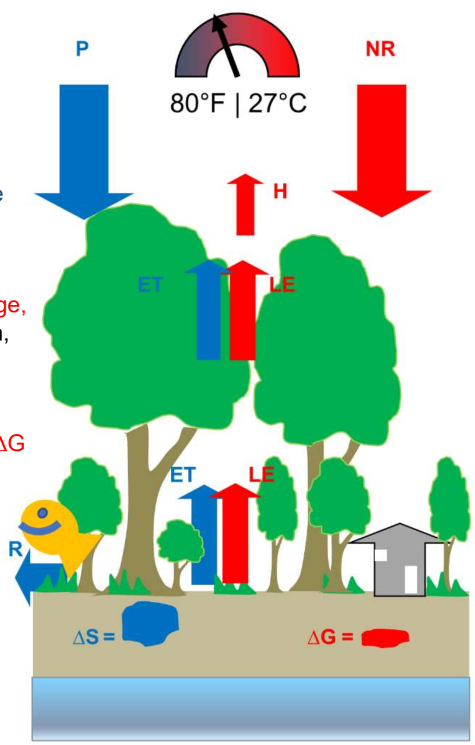
- Cooling Heat Islands — i-Tree Cool Air
- Managing Stormwater — i-Tree Hydro
- Cooling River Waters — i-Tree Cool River
- Reducing Energy Use — i-Tree Energy
- Mapping Nutrient Runoff — i-Tree Buffer

i-Tree Tools as Numerical Models of Forest Structures, Functions, Services, Benefits & Values

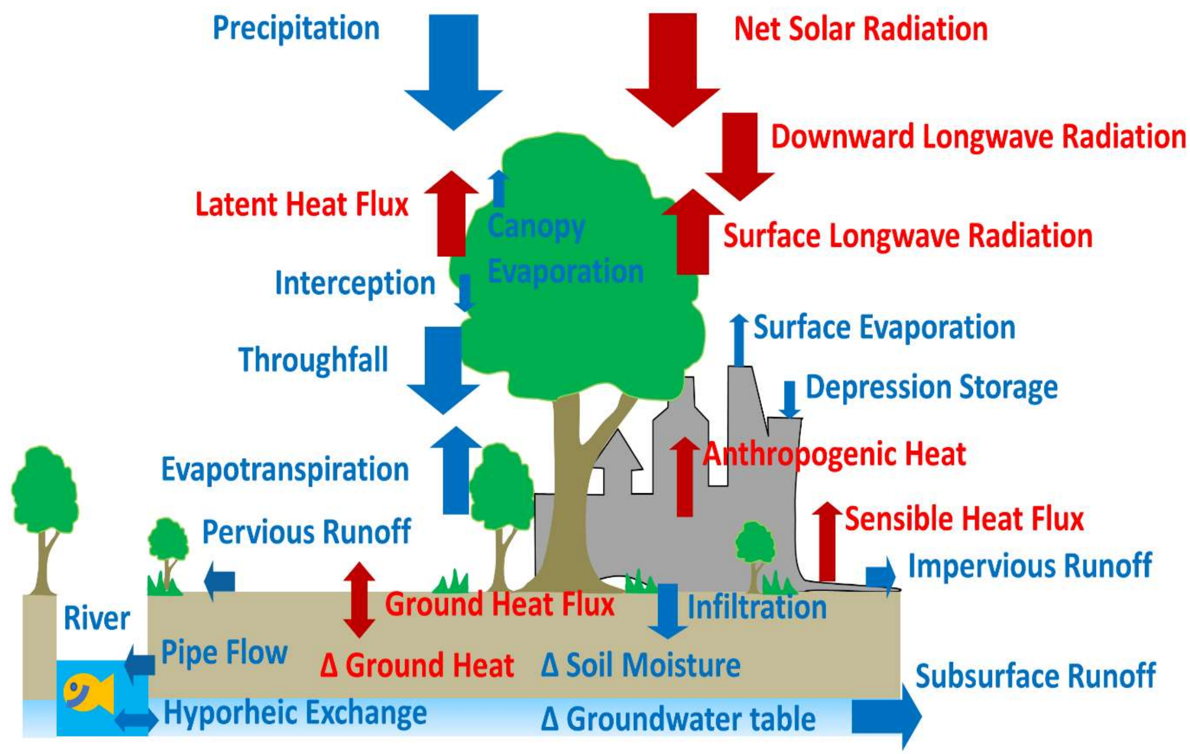
Legend:

P = precipitation,
R = runoff,
ET = evapotranspiration,
ΔS = change in water storage
NR = net radiation,
H = sensible energy,
LE = latent energy,
ΔG = change in energy storage,
λ = latent heat of vaporization,
ρ_w = density of water

Water Balance: $P=R+ET+\Delta S$
Energy balance: $NR=H+LE+\Delta G$
$ET = LE / (\lambda \rho_w)$



Rural Forest

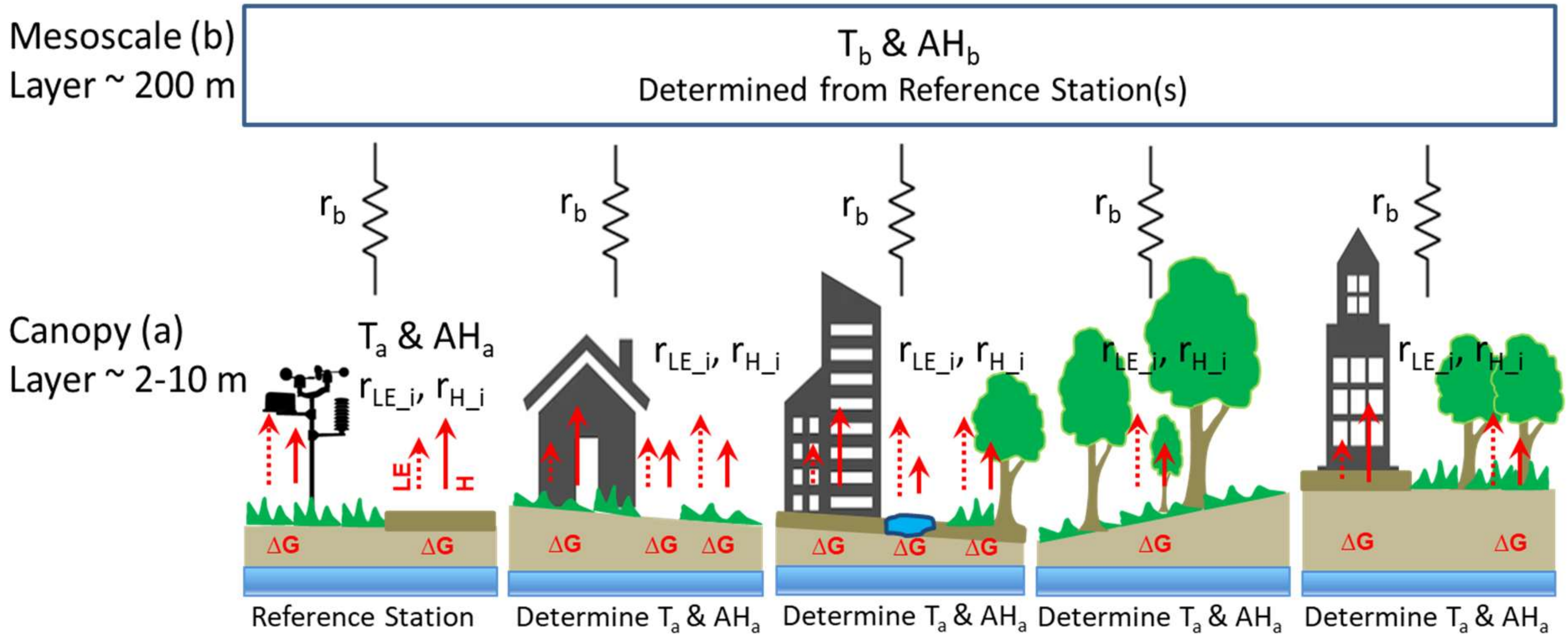


Endreny, T. A. (2022). i-Tree Tools Assist with Strategically Designing Tree Cover and Improving Community Resilience. *Clear Waters - NYWEA, 52*(1), 46-50.
Endreny, T. A. (2018). Strategically growing the urban forest will improve our world. *Nature Communications, 9*(1), 1160. doi:10.1038/s41467-018-03622-0

i-Tree Cool Air Model Theory
Spatially Distributed, Vertical Energy & Water Balance

Legend:

T = Air temperature
AH = Absolute humidity
b = Mesoscale height ~ 200 m
a = Urban canopy height ~ 2-10 m
i = Grid land cover type
C_i = Fractional coverage, sum to 1
H = Sensible energy or heat flux
LE = Latent energy or heat flux
PLE = Potential LE
R_n= Net radiation, SW+LW
ΔG = Ground heat flux
Δt = Time step
D = Depression storage on ground
S = Interception storage in canopy
$a_{1\text{-}3}$= Coef in Objective Hysteresis M
$r_{a/b}$ = aerodynamic resistance
r_s = surface or stomatal resistance
λ = latent heat of vaporization
ρ_w = density of water
C_p = specific heat constant pressure



Yang, Y., Endreny, T. A., & Nowak, D. J. (2013). A physically based analytical spatial air temperature and humidity model. *Journal of Geophysical Research-Atmospheres, 118*(18), 10449-10463. doi:10.1002/jgrd.50803

i-Tree Hydro Supporting Cool Air with Dynamic Wetness Likelihood & Groundwater Depths

$$q_i = P_w \cdot a_i$$

$$q_i = T_i \cdot tan\beta_i$$

$$T_i = T_o \cdot exp\left(^{-S_i}/_m\right)$$

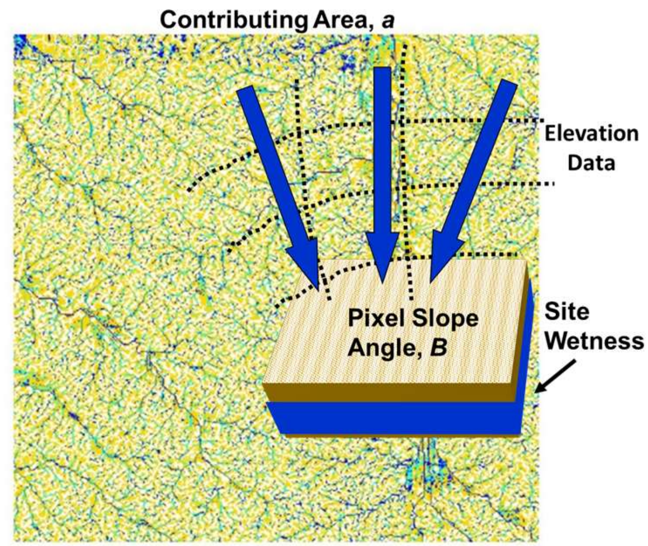
$$S_i = m\left[ln\left(^R/_{T_o}\right) + ln\left(^{a_i}/_{tan\beta_i}\right)\right]$$

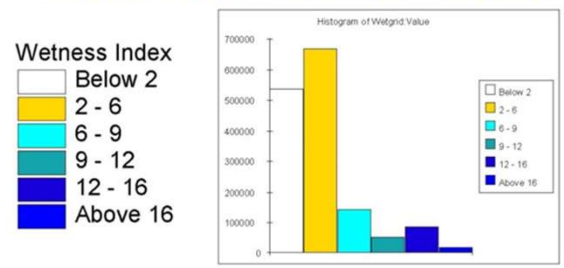
$$TI_i = ln\left(^{a_i}/_{tan\beta_i}\right)$$

$$\overline{S} = -m \cdot ln\,^R/_{T_o} - m \cdot \overline{TI}$$

$$Q_{sub} = T_o \cdot exp(-\overline{TI}) \cdot exp\left(-^{\overline{S}}/_m\right)$$

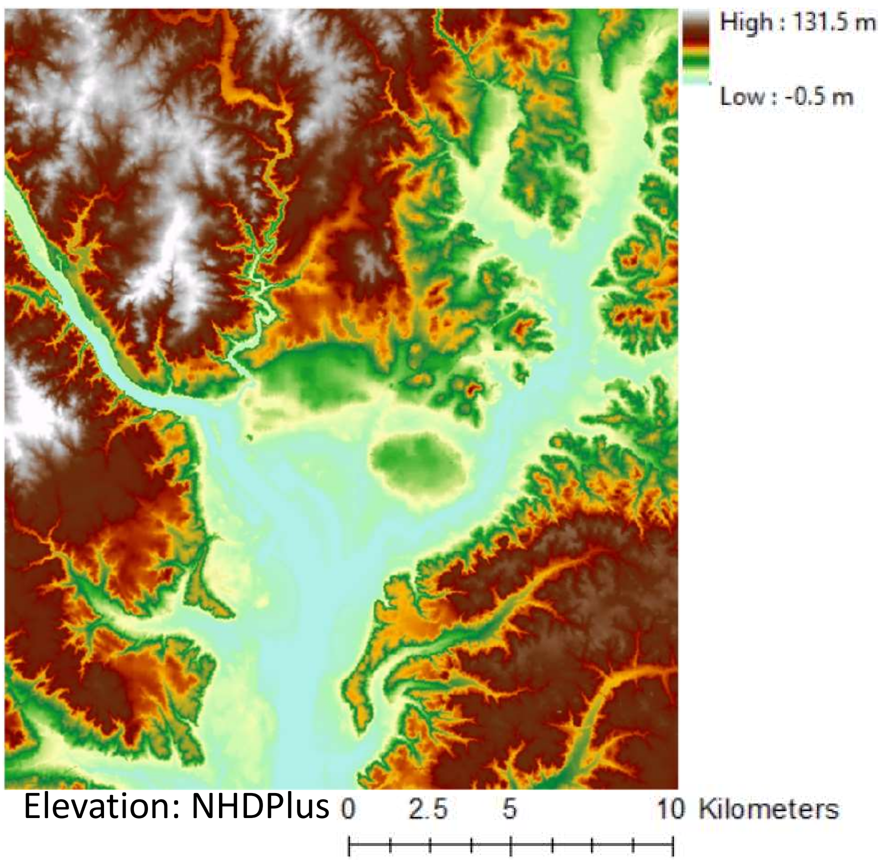
- q_i is subsurface discharge (m^2/hr)
- i is pixel element
- P_w is precipitation as recharge (m/hr)
- a_i is local basin area per unit width (m)
- T_i is local transmissivity (m^2/hr)
- $tan\beta_i$ is local tangent of hillslope angle
- T_o is local saturated transmissivity (m^2/hr)
- S_i is local soil moisture deficit (m)
- m is a scaling parameter
- TI is topographic index
- $\overline{S}$, $\overline{TI}$ is basin average values
- Q_{sub} is subsurface flow (m^3/hr)



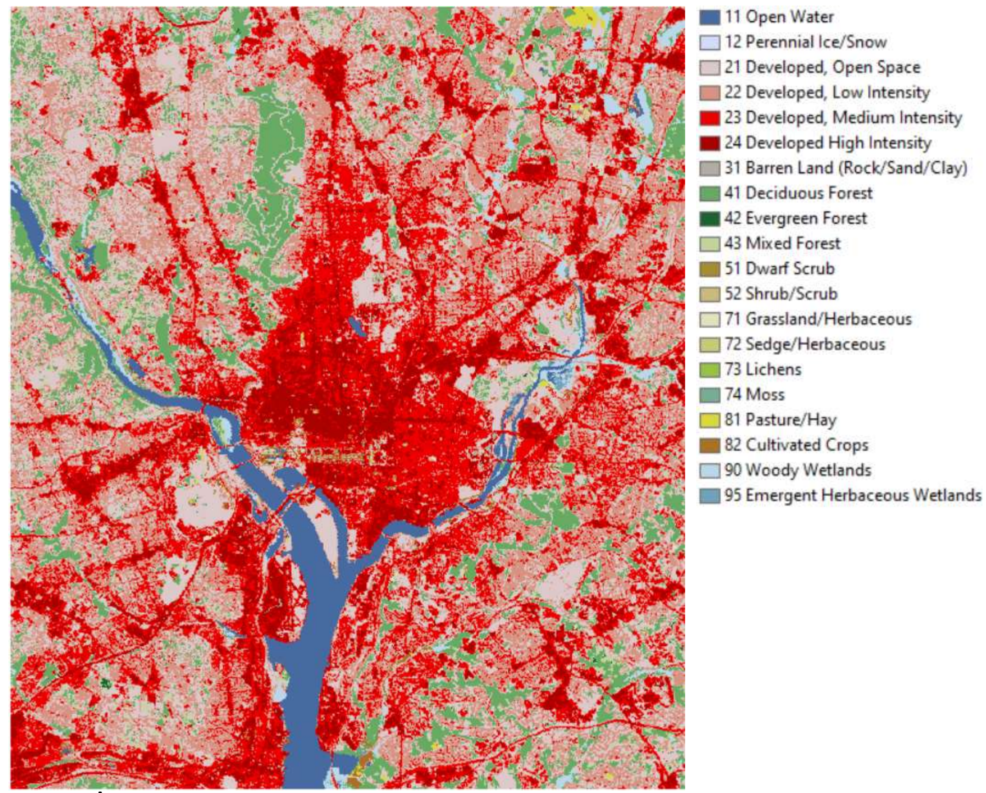


Wang, J., Endreny, T. A., & Nowak, D. J. (2008). Mechanistic Simulation of Tree Effects in an Urban Water Balance Model. Journal of the American Water Resources Association, 44(1), 75-85. doi:10.1111/j.1752-1688.2007.00139.x

Inputs for i-Tree Cool Air: Elevation and Land Cover for Washington, DC

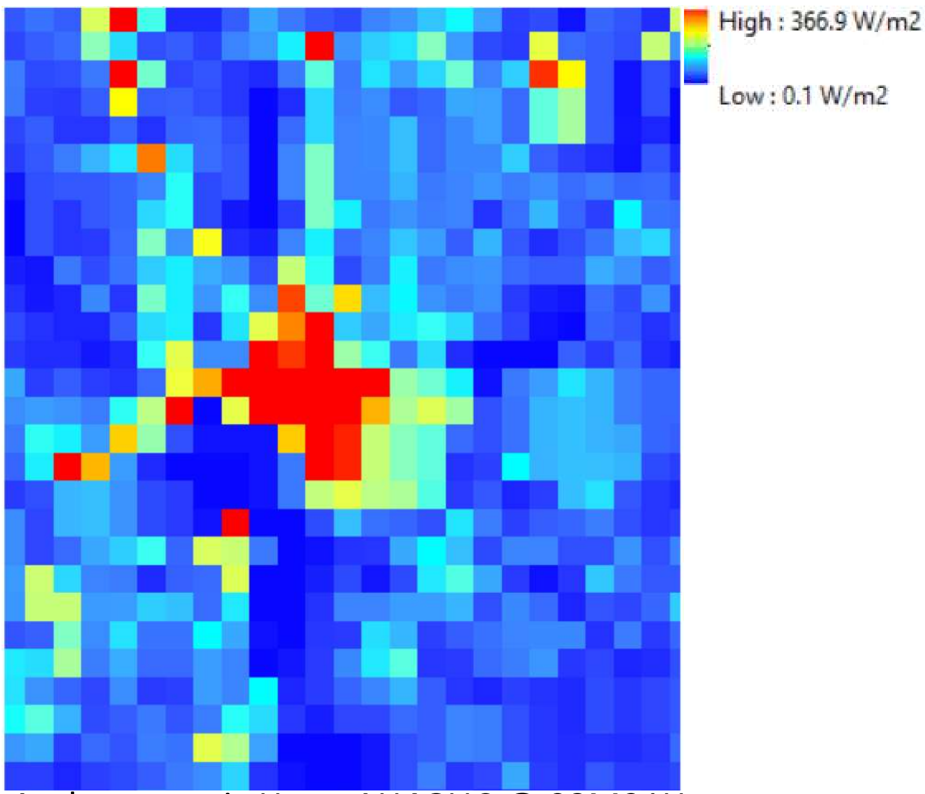


Elevation: NHDPlus

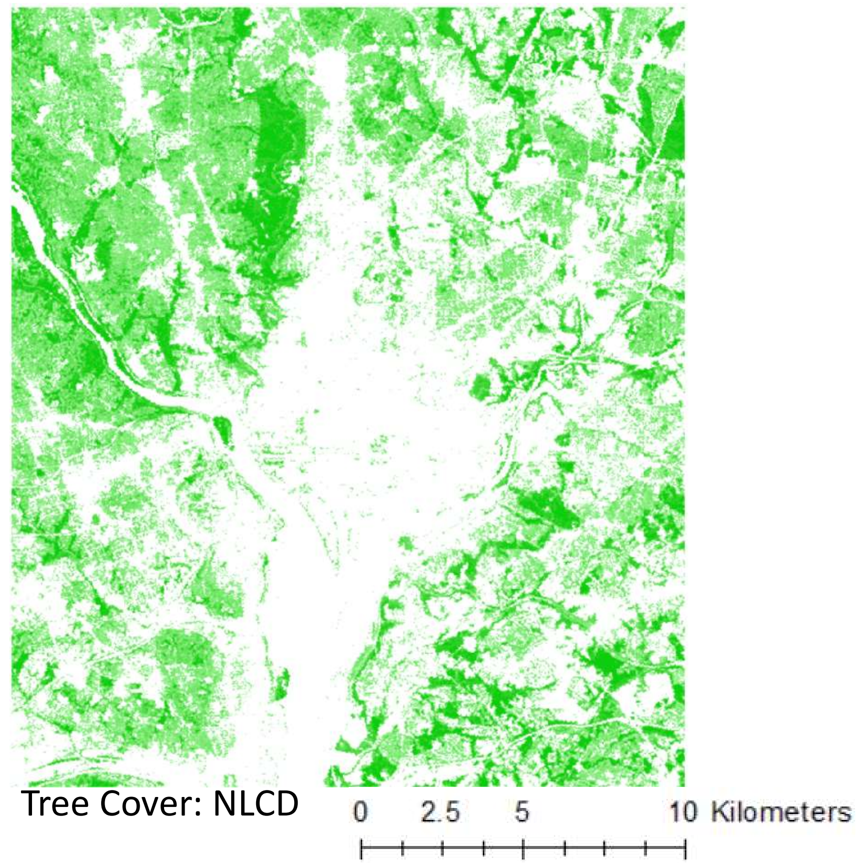


Land Cover: NLCD

Inputs for i-Tree Cool Air: Anthropogenic Heat, Tree & Impervious Cover for Washington, DC

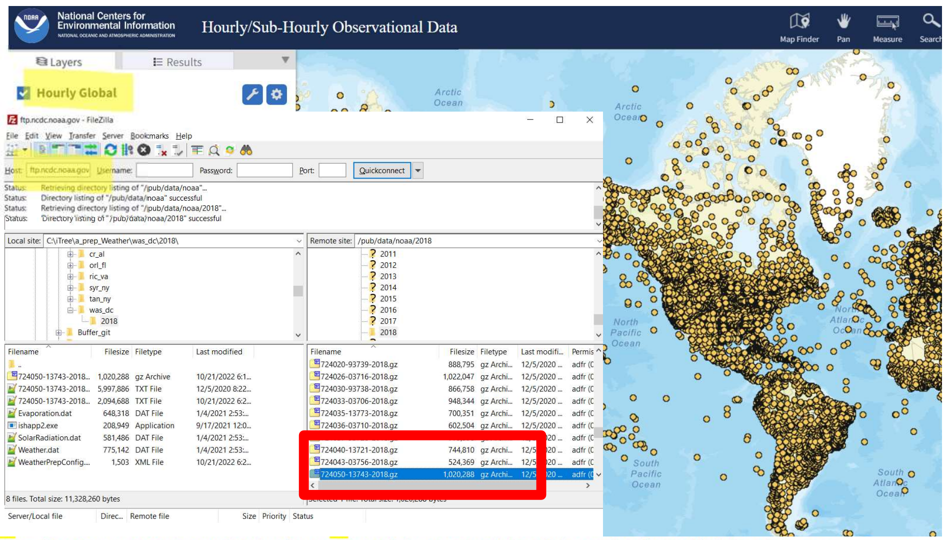


Anthropogenic Heat: AH4GUC @ 08M21H



Tree Cover: NLCD

Input Meteorological Data: Single Pixel Time Series of Observations using WeatherPrep.exe. Flow …




```
<!-- Program generates output of: weather.dat, evaporation.dat, and solarradiation.dat -->
<InputList>
  <Input>
    <Model>Hydro</Model><!-- Options: Hydro, Energy; Hydro generates 8 weather outputs, Energy generates 10
    <Nation>United States of America</Nation> <!-- Confirm name here: https://database.itreetools.org/#/loc
    <State>District of Columbia</State> <!-- Confirm name here: https://database.itreetools.org/#/locationS
    <County>District of Columbia</County> <!-- Confirm name here: https://database.itreetools.org/#/locatio
    <Place>Washington</Place> <!-- Confirm name here: https://database.itreetools.org/#/locationSearch -->
    <MaximumLAI>5</MaximumLAI> <!-- Affects canopy resistance -->
    <EvergreenPercent>5</EvergreenPercent> <!-- Affects evaporation during leaf of period -->
    <VegetationType>Tree</VegetationType> <!-- Options: Tree, Shrub, or Grass -->
    <StartYear>2018</StartYear> <!-->Corresponds with input weather file -->
    <EndYear>2018</EndYear> <!-- Corresponds with input weather file -->
    <SurfaceWeatherDataFile>C:\iTree\a_prep_Weather\was_dc\2018\724050-13743-2018_out.txt</SurfaceWeatherDa
    <PrecipitationDataCsv></PrecipitationDataCsv> <!-- Optional Precip.csv to replace NOAA raw data values.
```

Command Prompt

```
C:\iTree\a_prep_Weather\was_dc\2018>ishapp2.exe 724050-13743-2018.txt 724050-13743-2018_out.txt
724050-13743-2018.txt
724050-13743-2018_out.txt

C:\iTree\a_prep_Weather\was_dc\2018>WeatherPrep C:\iTree\a_prep_Weather\was_dc\2018
System.String[]
Below are the input data from: C:\iTree\a_prep_Weather\was_dc\2018\WeatherPrepConfig.xml

Model is: Hydro
Nation is: United States of America
State is: District of Columbia
County is: District of Columbia
Place is: Washington
MaximumLAI is: 5
EvergreenPercent is: 5
VegetationType is: Tree
StartYear is: 2018
EndYear is: 2018
SurfaceWeatherDataFile with input data: C:\iTree\a_prep_Weather\was_dc\2018\724050-13743-2018_out.txt
PrecipitationDataCsv with input data:
LAIDatabase for output is: C:\iTree\a_prep_Weather\was_dc\2018\LAI.csv
WeatherDatabase for output is: C:\iTree\a_prep_Weather\was_dc\2018\Meteo.csv

Databases being created to construct tree phenology and generate meteorological variables:
Leaf area index timeseries DB constructed for use in evapotranspiration calculations.
Meteorological timeseries DB constructed to generate output data files.

The following output files were written:
C:\iTree\a_prep_Weather\was_dc\2018\Weather.dat
C:\iTree\a_prep_Weather\was_dc\2018\Evaporation.dat
C:\iTree\a_prep_Weather\was_dc\2018\SolarRadiation.dat
```

```
yyyymmdd,Hr:Min:Sec,Tair(F),Tdew(F),NetRad(W/m^2),WndSpd(m/s),Precip(m/h)
20180828,00:00:00,79.98305085,76.
20180828,01:00:00,80.00000000,76.
20180828,02:00:00,78.84615385,76.
20180828,03:00:00,79.02366864,74.
20180828,04:00:00,78.00000000,75.
20180828,05:00:00,78.00000000,75.
20180828,06:00:00,78.00000000,75.
20180828,07:00:00,79.00000000,76.
20180828,08:00:00,80.15384615,76.
20180828,09:00:00,82.28402367,76.
20180828,10:00:00,87.00000000,75.
20180828,11:00:00,89.30769231,73.
20180828,12:00:00,91.26035503,75.
20180828,13:00:00,92.00000000,75.
20180828,14:00:00,92.00000000,72.
20180828,15:00:00,93.15384615,73.
20180828,16:00:00,92.00000000,72.
20180828,17:00:00,90.84615385,73.
20180828,18:00:00,87.56213018,75.
20180828,19:00:00,86.00000000,75.
```

```
yyyymmdd,Hr:Min:Sec,DirSW(W/m^2),DiffSW(W/m^2),DownLW(W/m^2),UpLW(W/m^2),
Latitude(Radian),HourAngle(Radian),DeclinationAngle(Radian)
20180828,00:00:00,0.00,0.00,445.79,458.09,0.6792,-3.1839,0.1744
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```
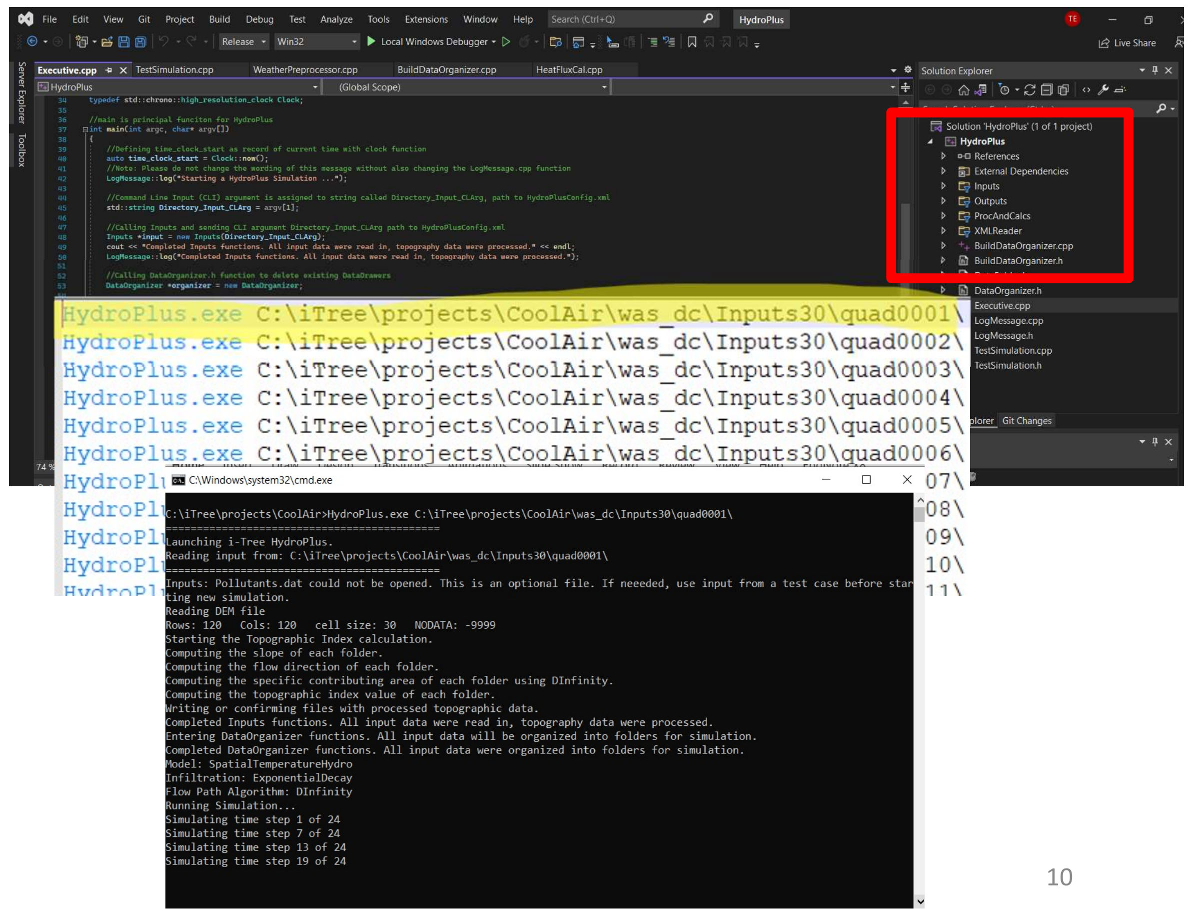
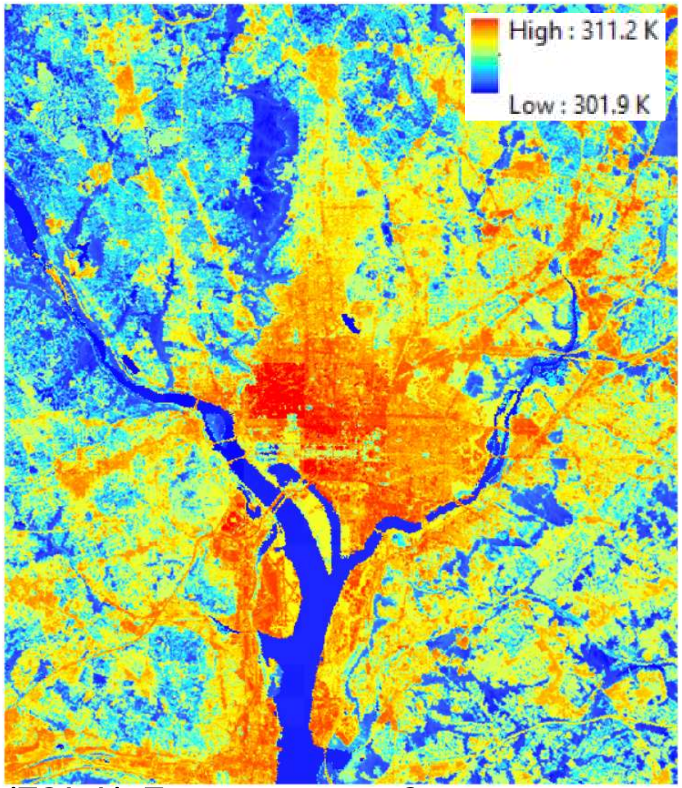
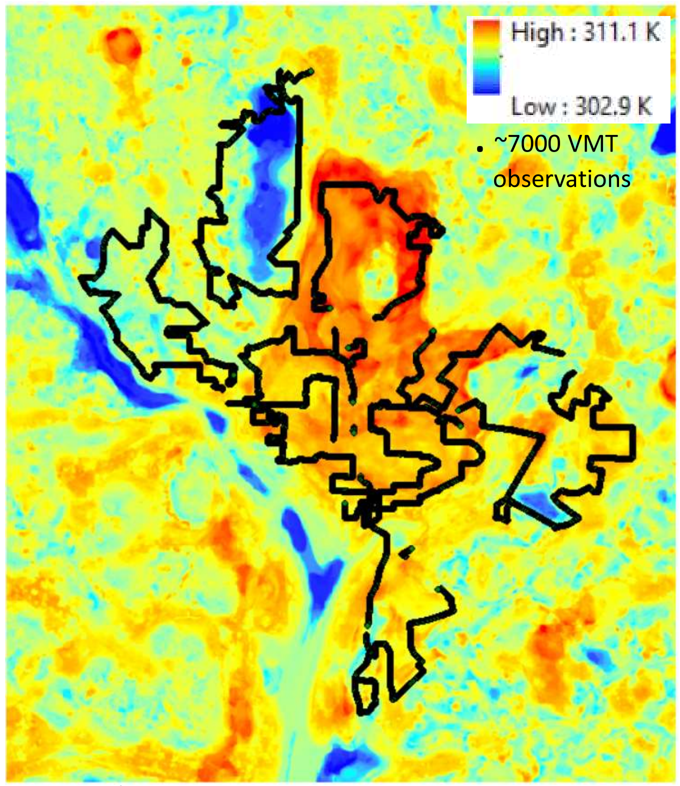

i-Tree HydroPlus Configuration File w/ Parameter Settings, Visual Studio Editor, Batch Runs. Flow …



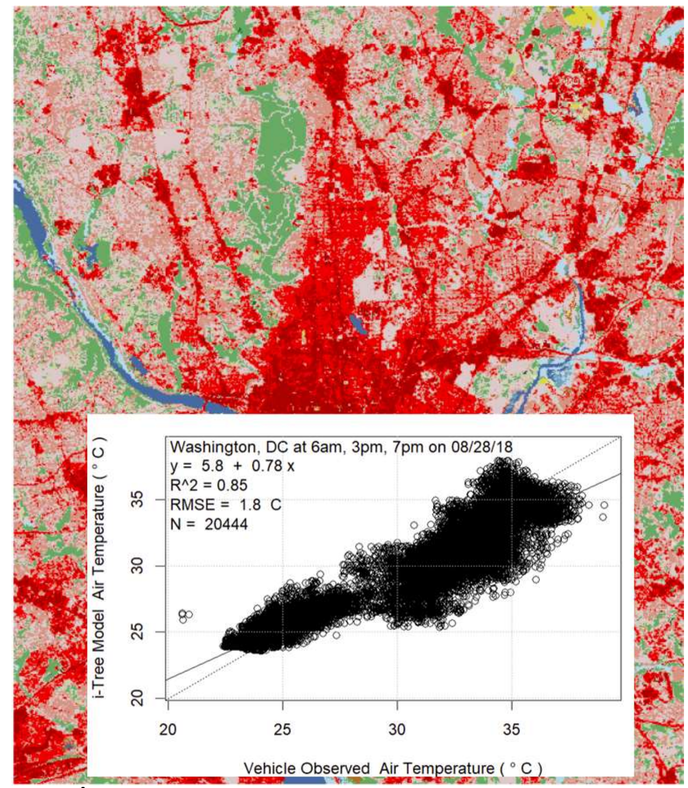
Validating i-Tree Cool Air: Washington, DC @ 6AM, 3 & 7 PM 8/28/18, Data from Prof. V. Shandas



iTCA Air Temperature at 3 pm



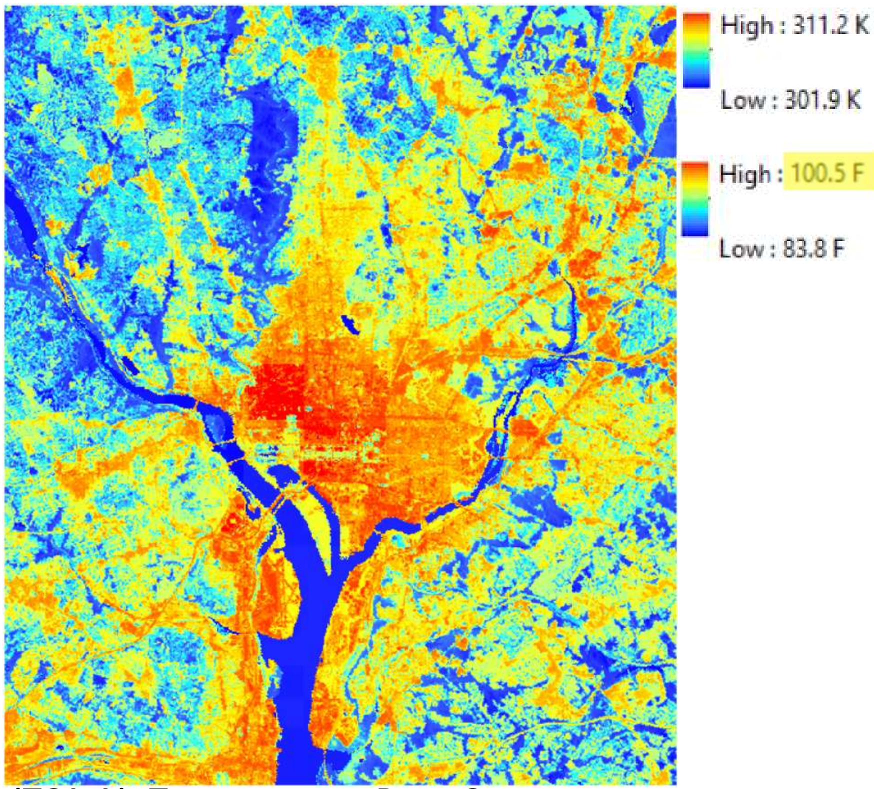
VMT Air Temperature at 3 pm



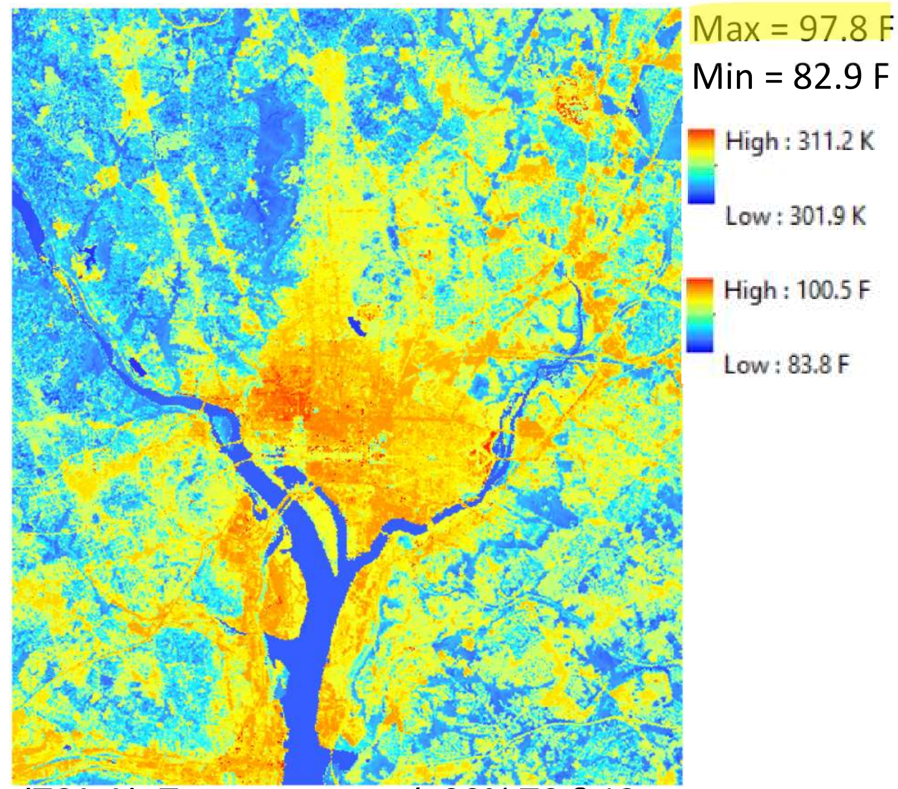
Land Cover: NLCD

Shandas, V., Voelkel, J., Williams, J., & Hoffman, J. (2019). Integrating Satellite and Ground Measurements for Predicting Locations of Extreme Urban Heat. *Climate, 7*(1), 5.
Yang, Y., Endreny, T. A., & Nowak, D. J. (2013). A physically based analytical spatial air temperature and humidity model. JGR-Atmospheres, 118(18), 10449-10463. doi:10.1002/jgrd.50803

Output of Scenario Differences: Map of Temperature for Base Case vs +/-20% TC & IC



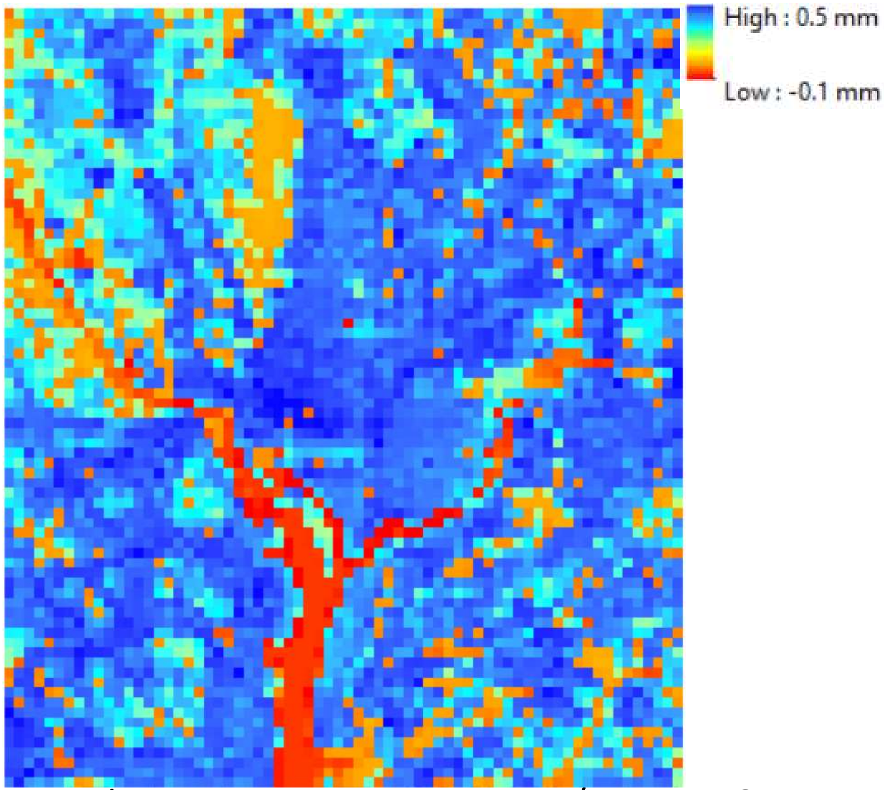
iTCA Air Temperature: Base Case



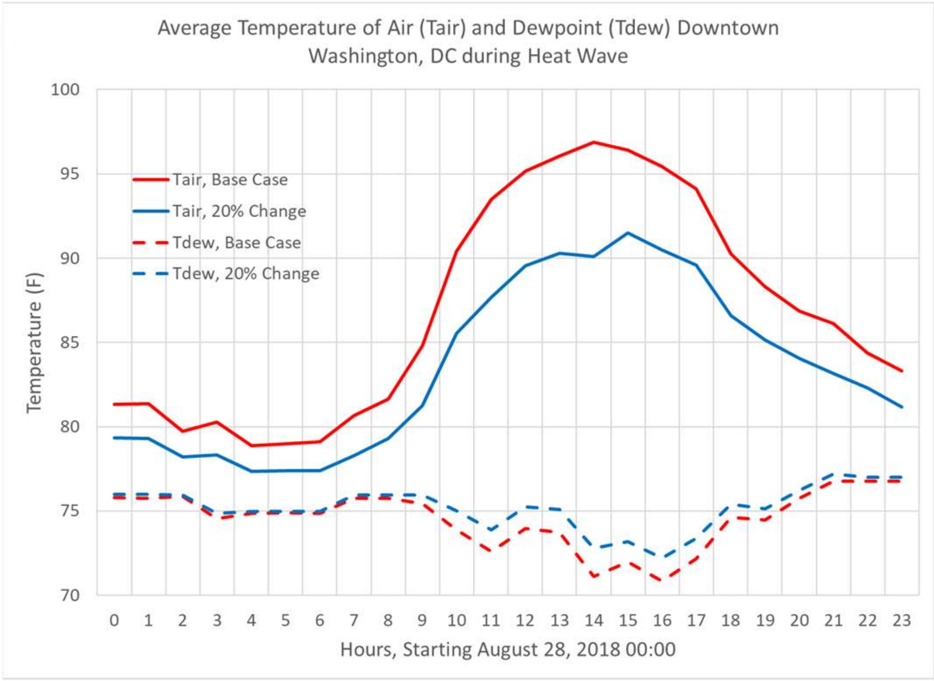
iTCA Air Temperature: +/- 20% TC & IC

Sinha, P., Coville, R. C., Hirabayashi, S., Lim, B., Endreny, T. A., & Nowak, D. J. (2022). Variation in Estimates of Heat-Related Mortality Reduction due to Tree Cover in U.S. Cities. Journal of Environmental Management, 301, 113751. doi:https://doi.org/10.1016/j.jenvman.2021.113751.

Output of Scenario Differences: Map of Evaporation, Time Series of Temperature

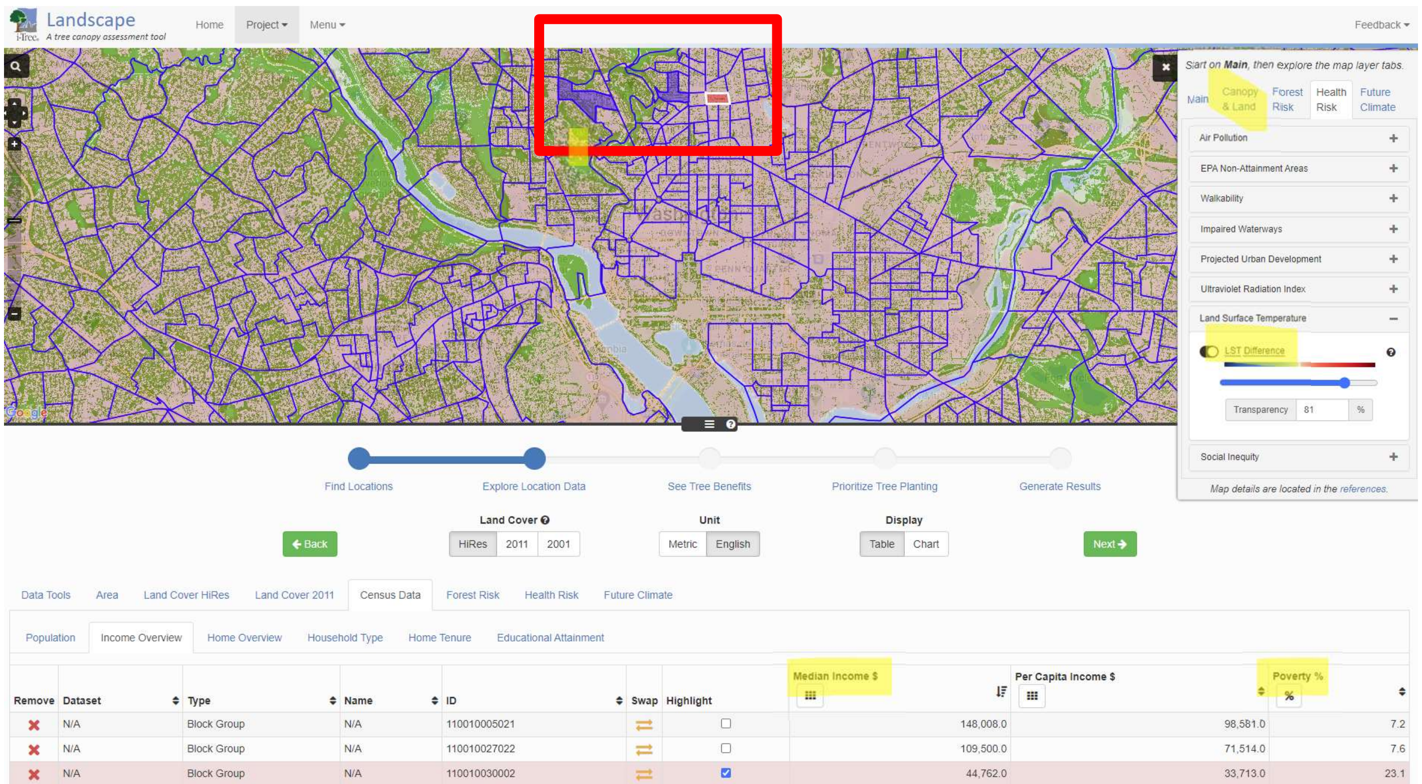


iTCA Change in Evaporation: Base +/- 20% TC & IC



iTCA Time Series of Base Case vs Scenario +/- 20% TC & IC

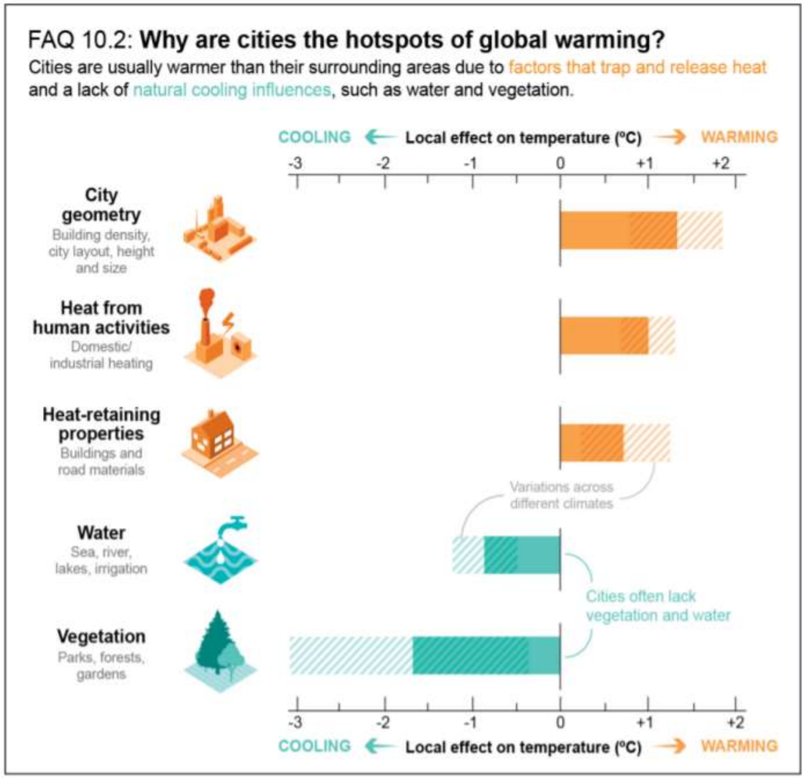
Discussion: i-Tree Landscape Finds Vulnerability via Overlay of Demographic Data & Ecosystem Services



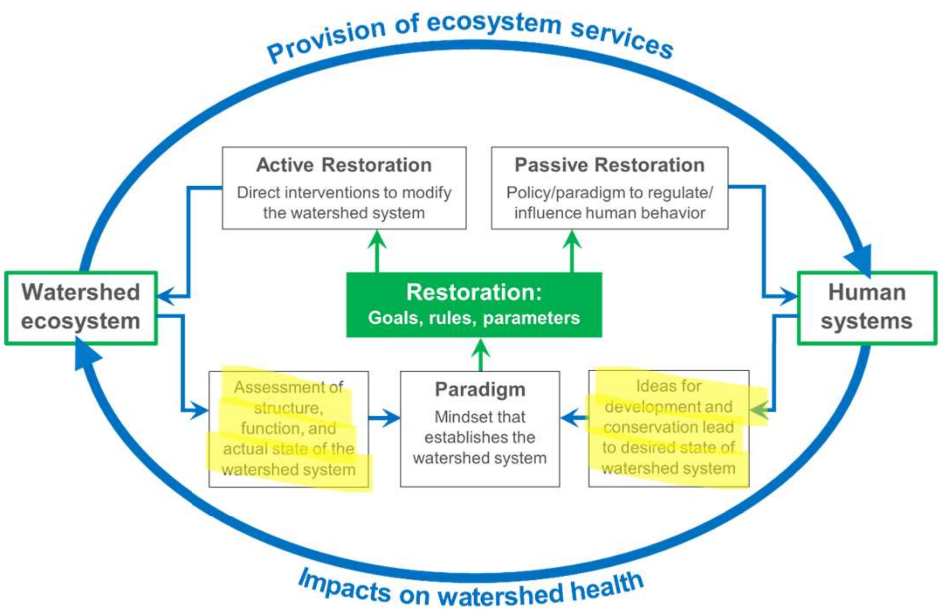
Exploring 3 Census Block Groups w/ Table of Income Overview & Map Overlay w/ HiRes Tree Cover, LST (Land Surface Temperature) Difference from Median of LandSAT scene. Map & Table show Vulnerability.

Discussion: Climate Change Exacerbates Threats to Urban Sustainability

- IPCC AR6 WG1 Physical Science Basis
  - Based on CMIP6, assessing multiple RCPs and SSPs
- Model, Observational, & Attribution Findings: Regional Fact Sheets
  – Forecast North American urban areas receive more extreme air pollution episodes in heavily polluted environments
  – Forecast Urban Areas receive more frequent extreme climate events, such as heatwaves, with more hot days and warm nights adding to heat stress in cities
  – Forecast Urban Areas receive sea level rise, storm surge, and extreme rainfall events will increase the probability of flooding

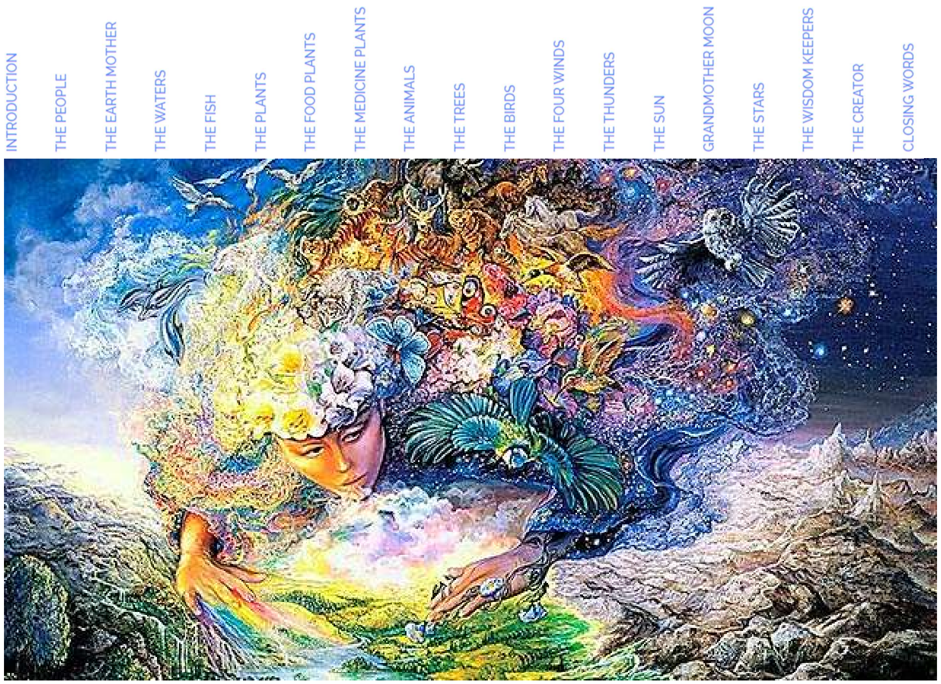


Discussion: Leverage Points to Improve the State of our Watershed; Resetting our Paradigms



Watershed state or conditions reveals its purpose.

Endreny, T. A. (2020). Leverage Points Used in a Systems Approach of River and River Basin Restoration. *Water, 12*(9). doi:10.3390/w12092606



https://danceforallpeople.com/haudenosaunee-thanksgiving-address/haudenosaunee-thanksgiving-address-2/

Today we have gathered and we see that the cycles of life continue.

...

Now our minds are one.

i-Tree

Do you?

i-Tree is a Cooperative Initiative

Arbor Day Foundation