

Pavements and the Urban Heat Island Effect

EPA's Cool Pavements Webcast

1/28/2010

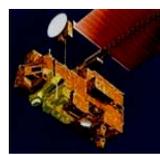
2-3:30 EST

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Arizona State University

Do Pavements contribute to UHI?

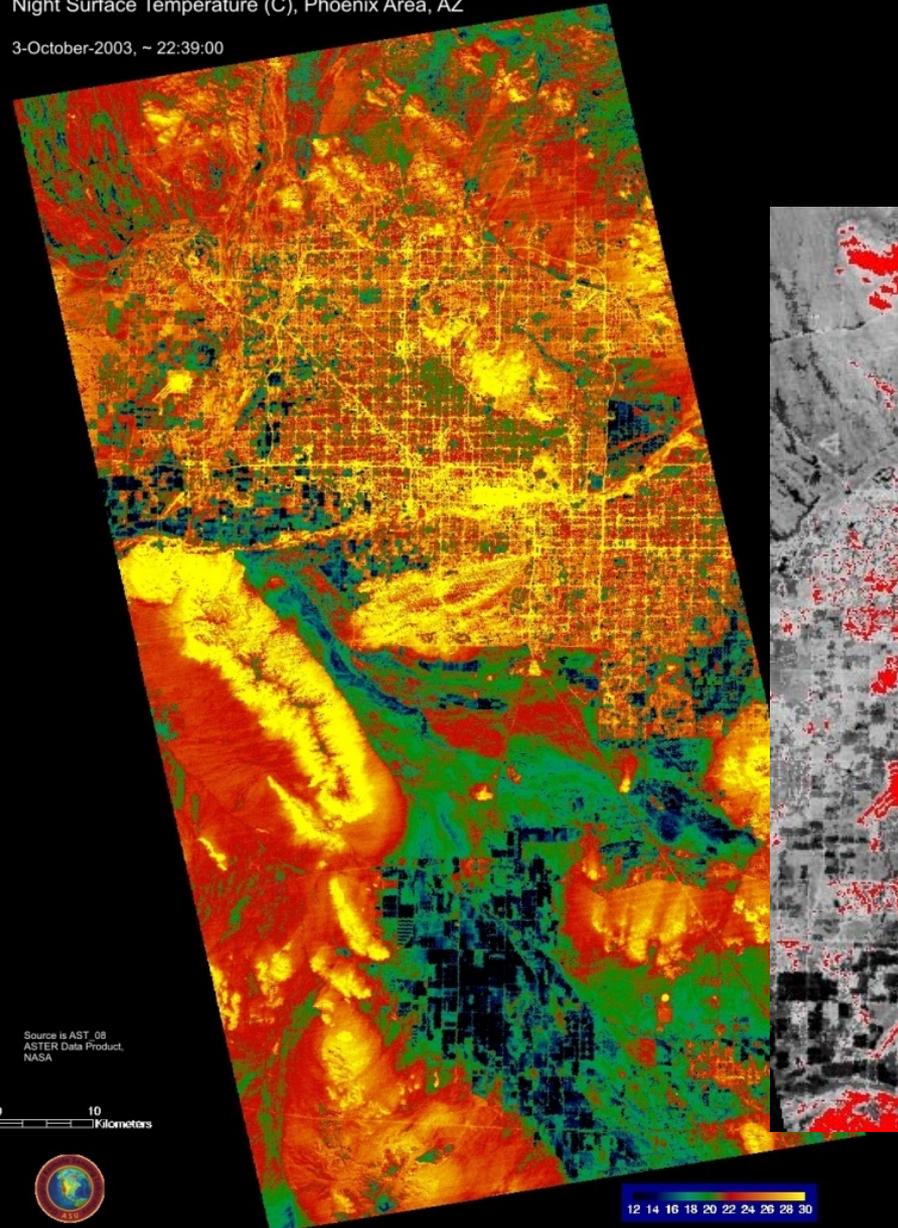
- If so:
 - How much and where?
- What are the:
 - evaluation techniques?
 - driving factors?
 - properties of materials?
 - design characteristics?
 - mitigation strategies and opportunities to pavements industries?
 - tools and models?



ASTER Satellite Imagery

Night Surface Temperature (C), Phoenix Area, AZ

3-October-2003, ~ 22:39:00



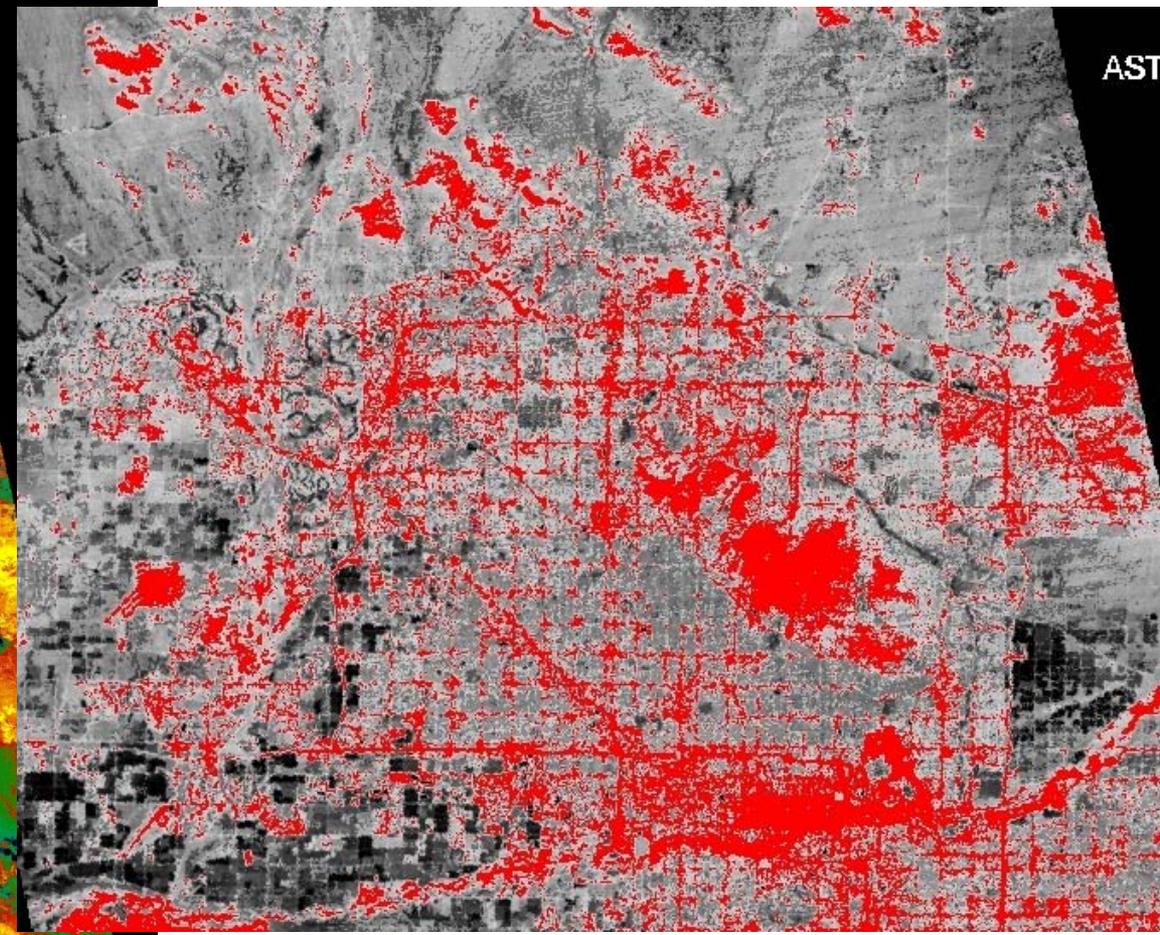
Source is AST_08
ASTER Data Product,
NASA

0 10
Kilometers



12 14 16 18 20 22 24 26 28 30

Paved surfaces are 40% of the urbanized land cover in Phoenix and contribute to UHI

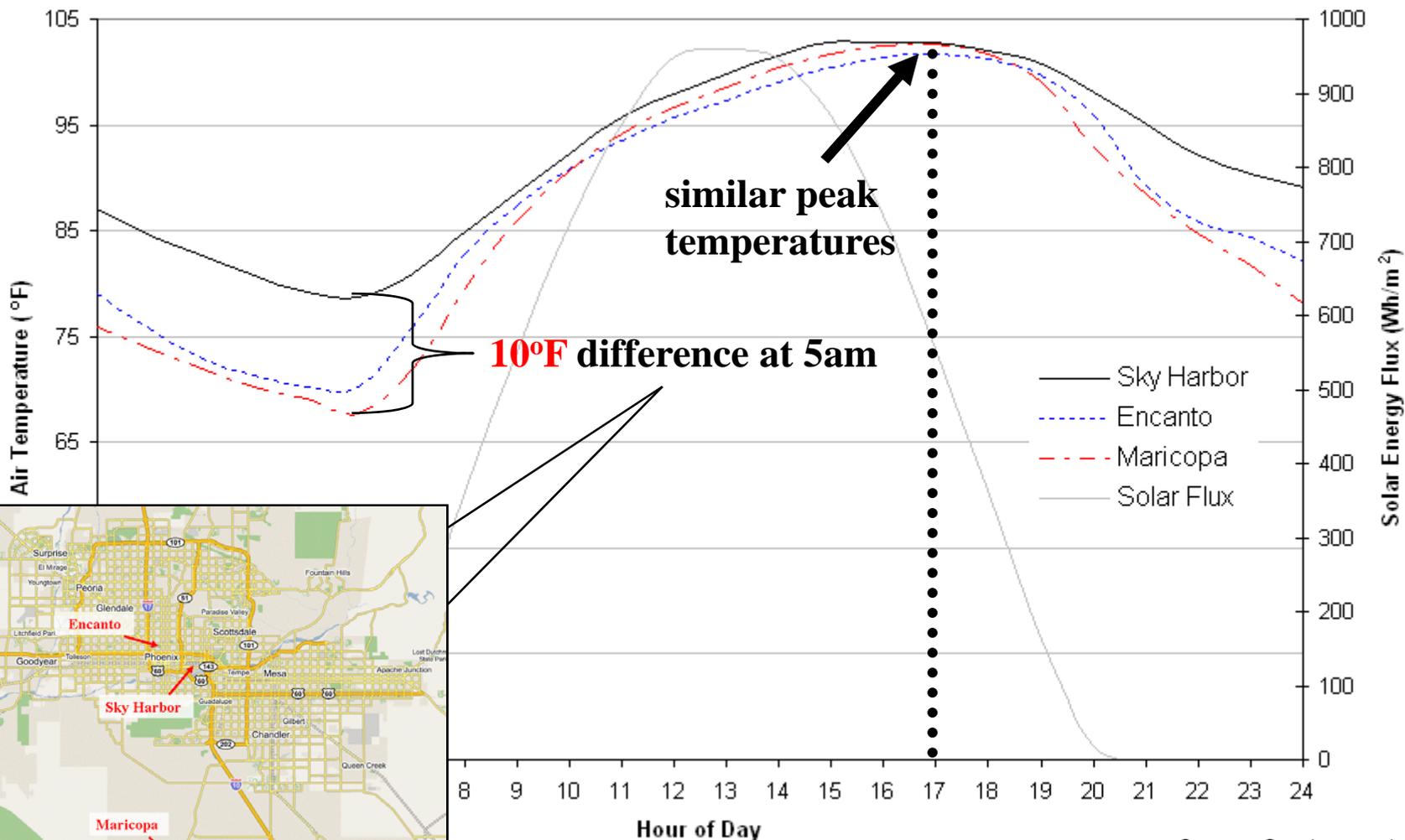


Phoenix Metropolitan Area (11pm at night)

AST

Average Hourly Air Temperatures (July 2005)

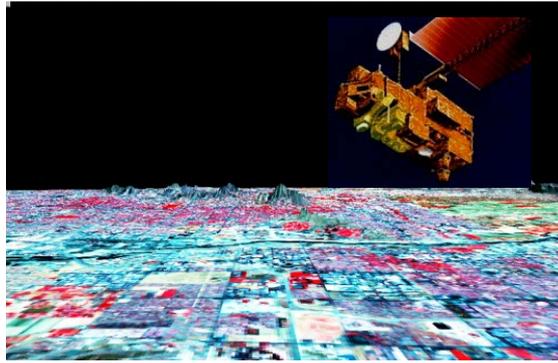
for Sky Harbor Airport (Urbanized), Encanto Park (Green Space), and the City of Maricopa (Rural)



Source: Otanicar et al. 2007

UHI Evaluation Techniques

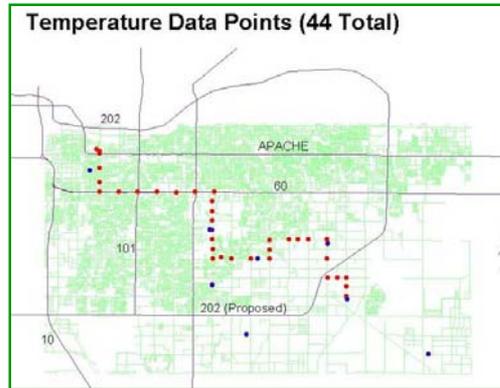
ASTER Thermal Imaging Satellite



IR Thermal Imagery



Mobile Transects



Embedded Thermocouples

Laboratory Testing





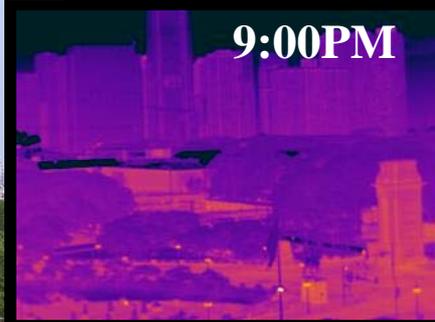
Time lapse infrared view of Chicago near Millennium Park July 14 – 15, 2007



5:00AM



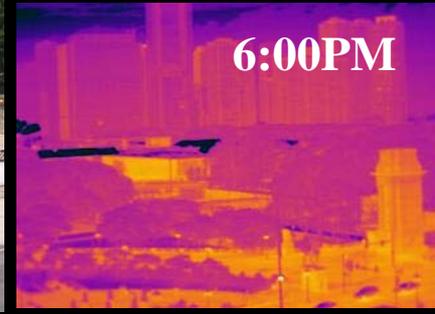
9:00PM



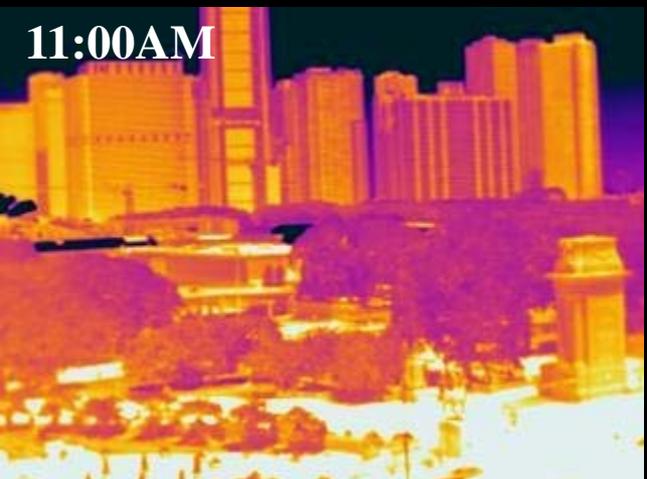
8:00AM



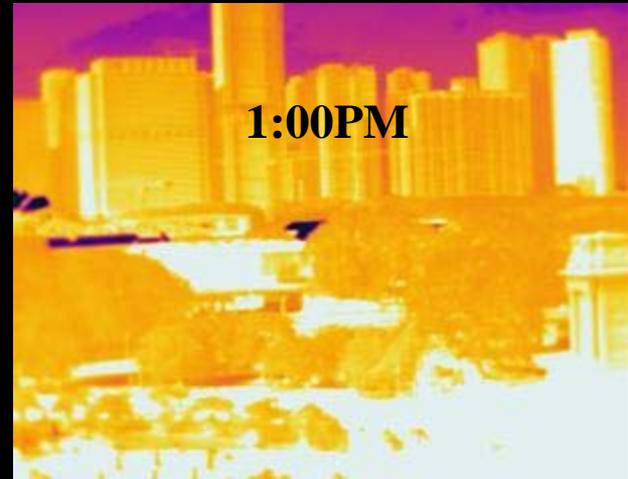
6:00PM



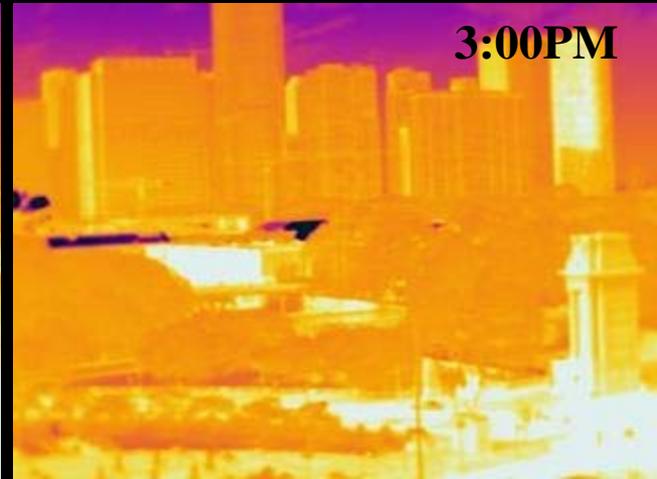
11:00AM



1:00PM

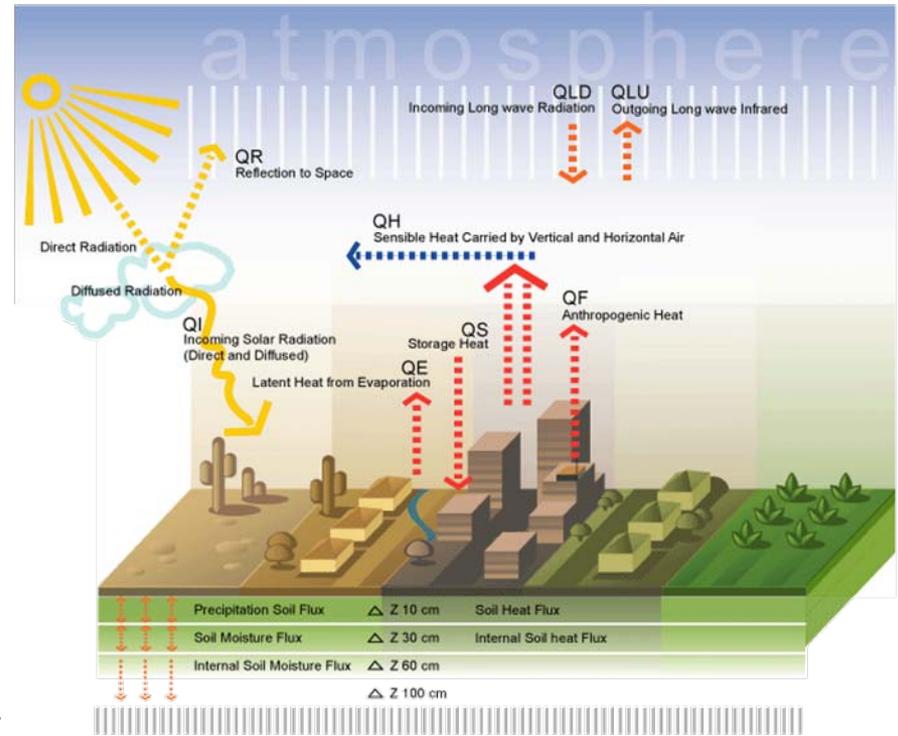


3:00PM



What are the driving factors?

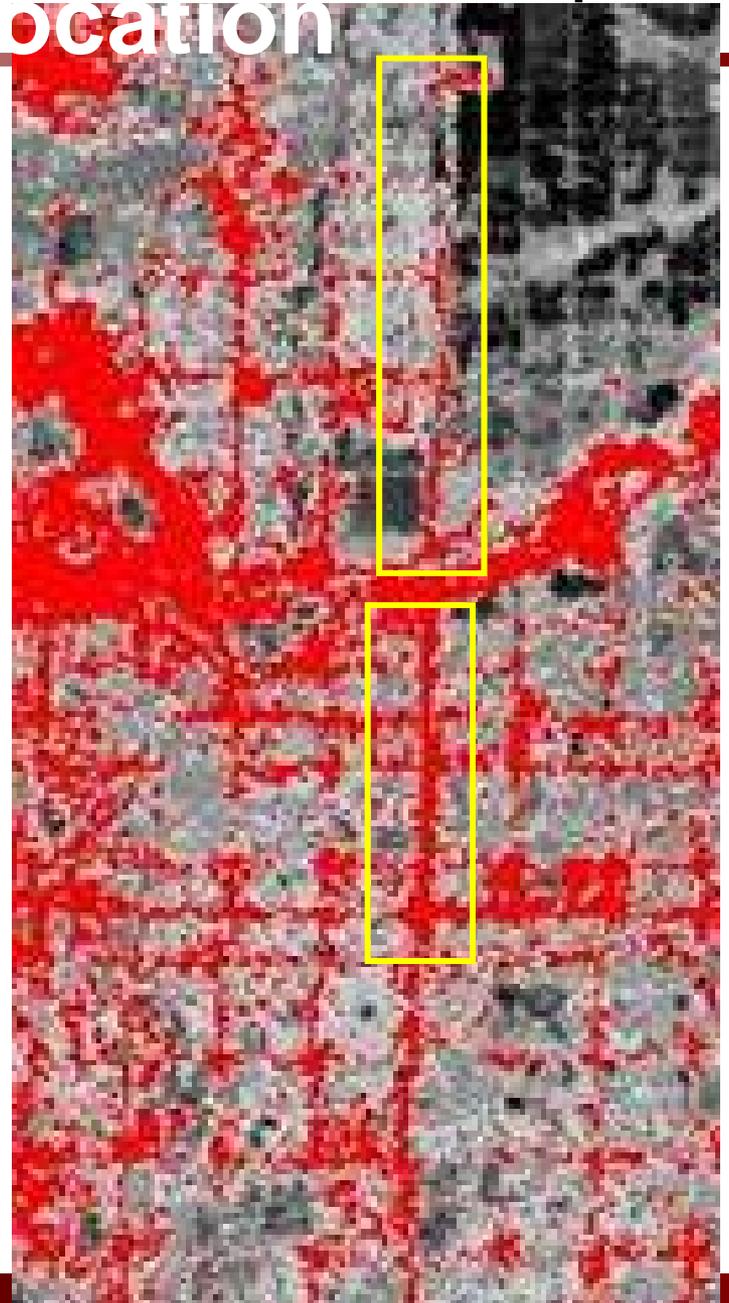
- ***Canyon Geometry***
- ***Thermal Properties***
- ***Anthropogenic Heat***
- ***The Urban Greenhouse Effect***
- ***The Effective Reflectivity (Albedo)***
- ***Reduction of Evaporating Surfaces***
- ***Reduced Turbulent Transfer of Heat***



■ Golden, Zehnder, Brazel 2004

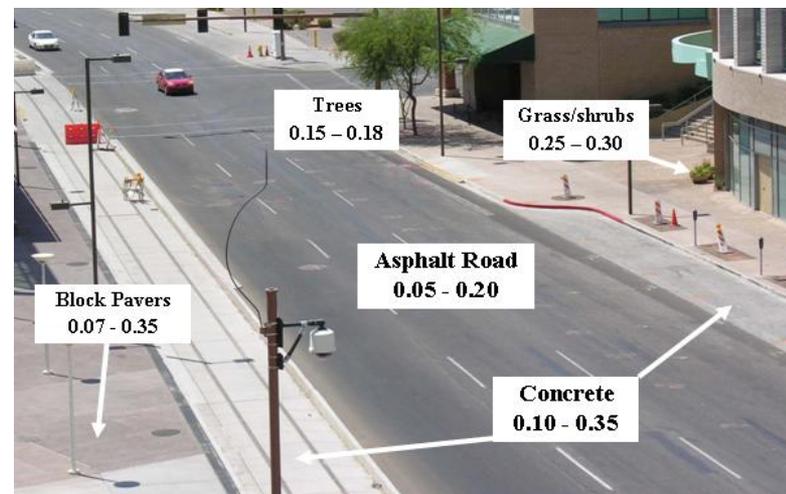
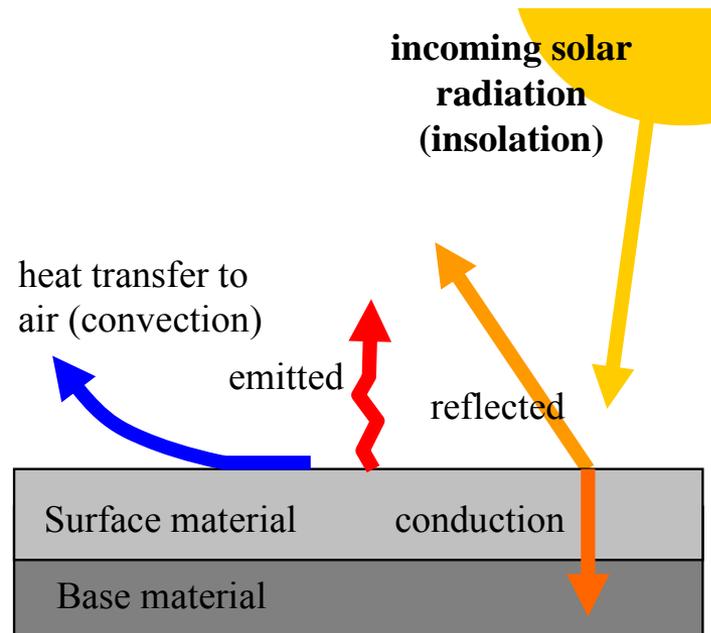
Example

Location



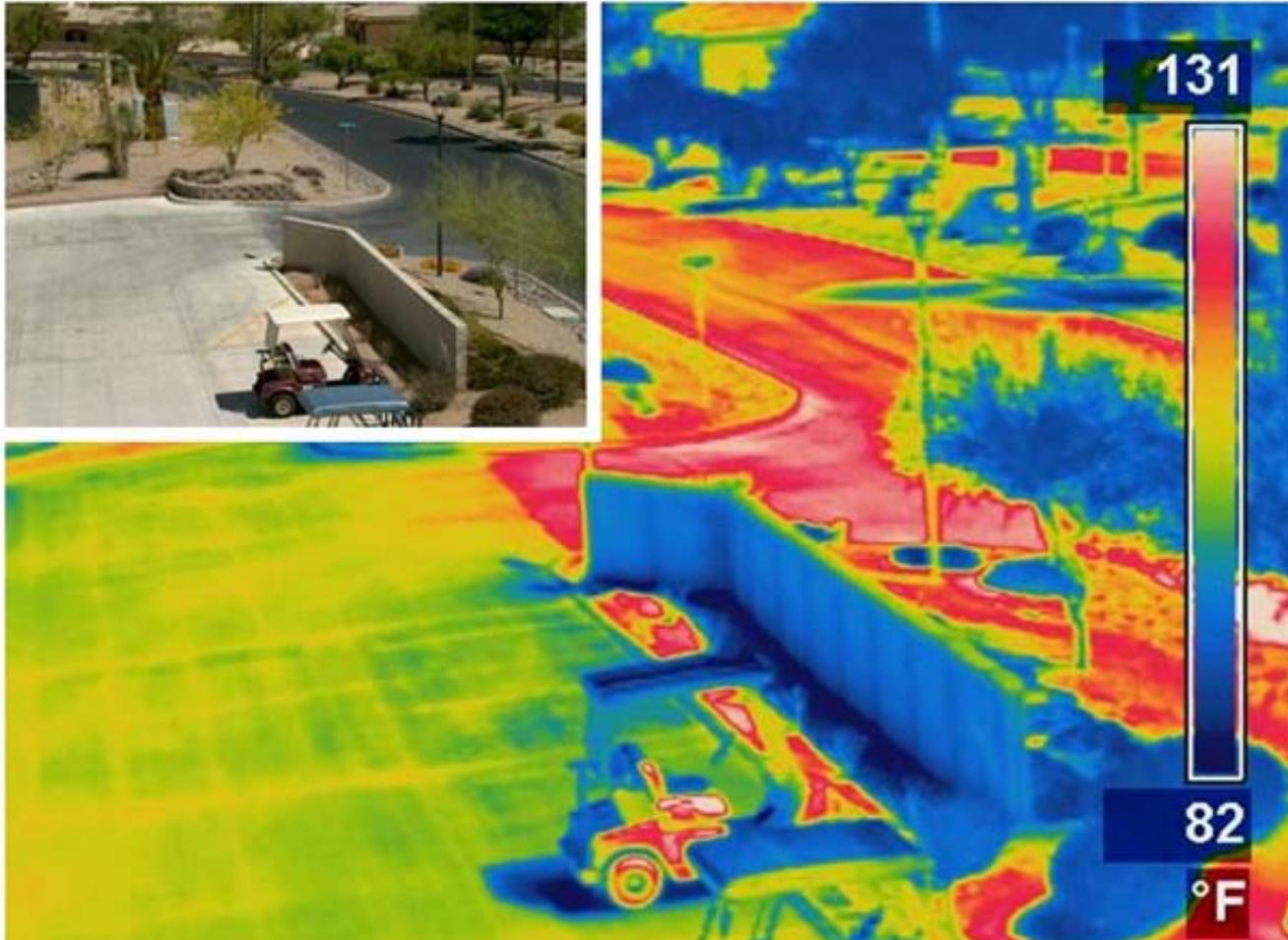
Fundamental Properties

- Albedo, α
- Emissivity, ε
- Convection Coefficient, h
- Thermal Conductivity, k
- Specific Heat, C
- Density, ρ
- Thermal Diffusivity, α, κ
- Porosity, ϕ



- Increase Albedo
 - Use pigments, light colored aggregates, resin binders
 - Surface coatings with nanoparticles
- Porous pavements (HMA and PCC)
- Whitetopping strategies
- Reflective Asphalt Pavements Techniques
- Thermal resistant materials
 - Aggregates, admixtures, crumb rubber
- Provide cover: trees, solar panels (parking structures)
- To pave or not to pave?

Thin and Ultra-Thin Whitetopping PCC



Reflective Asphalt Pavements

Surface Chip Seals and Coatings:
using reflective / light-colored chip / paints



“Gritting”:
reflective chips
and aggregate



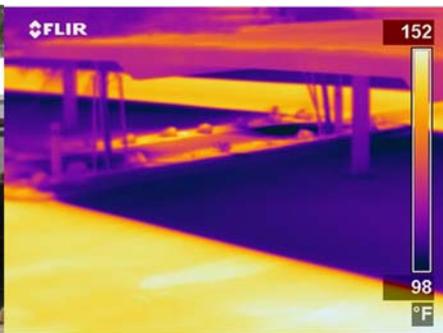
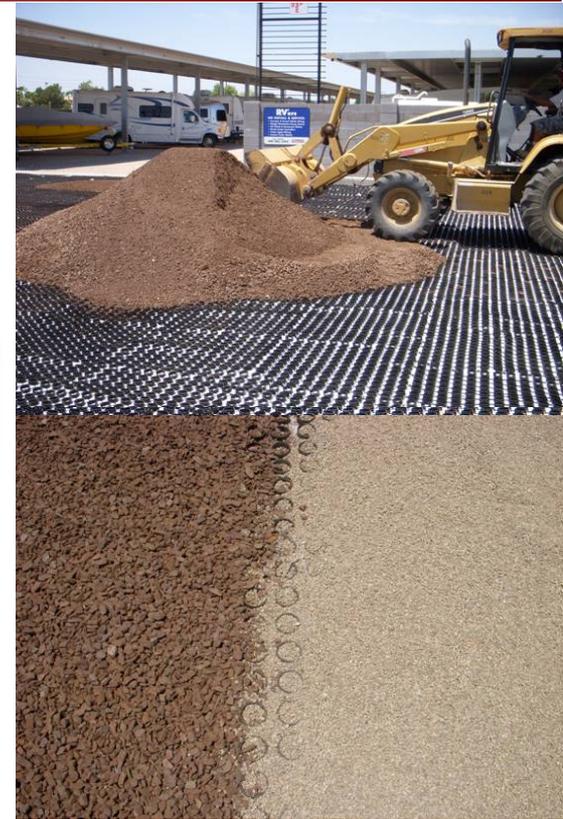
Shot-Blasting:
abrading surface binder



Pervious / Porous Parking Lots



U-haul : Permeable Pavement



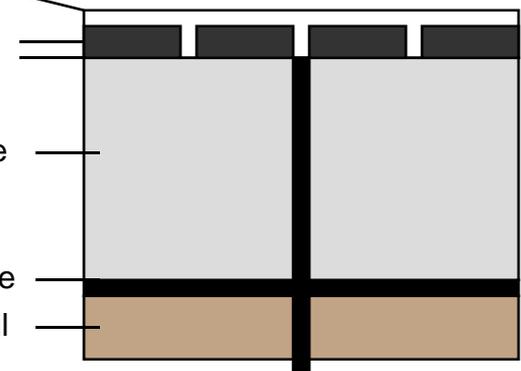
decorative rock filler

Plastic grid and
membrane

subbase

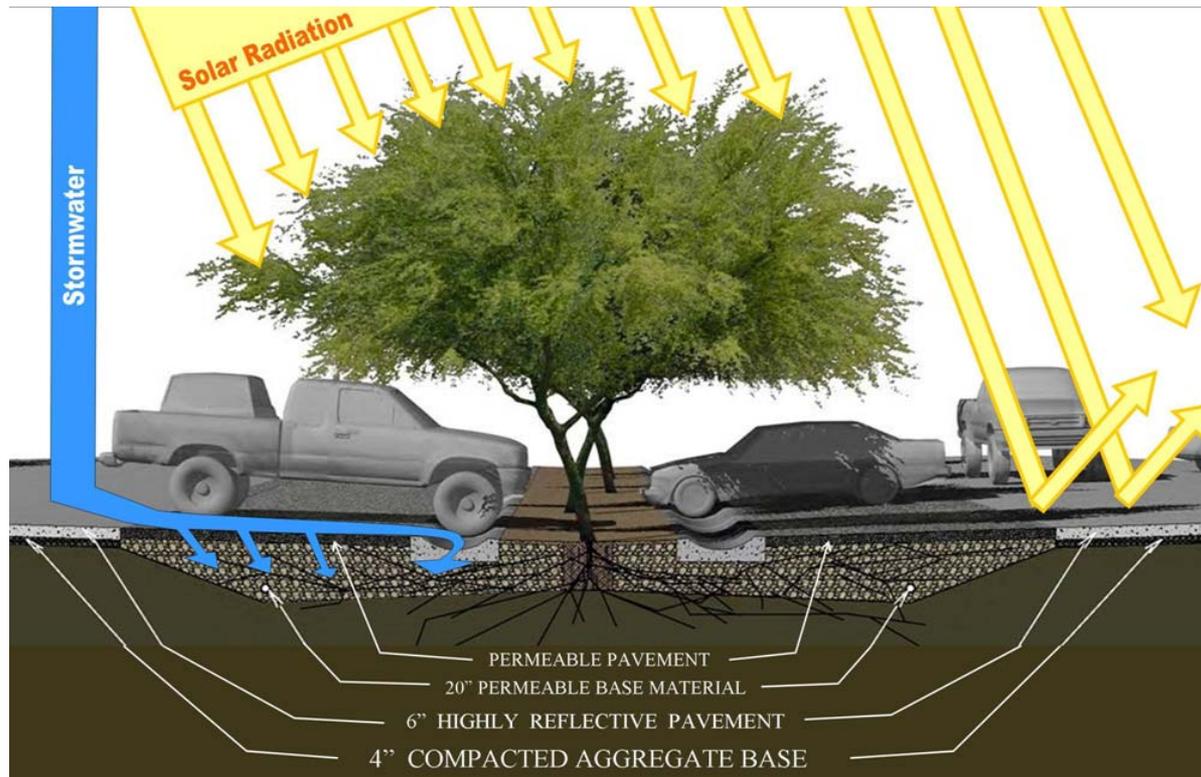
geotextile

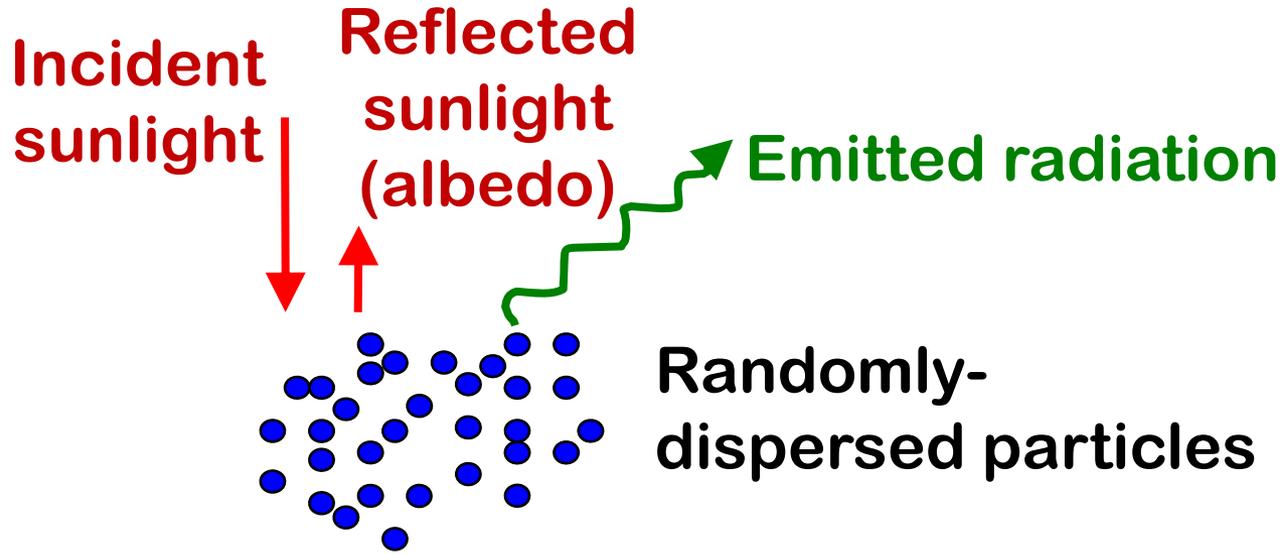
Sub grade soil



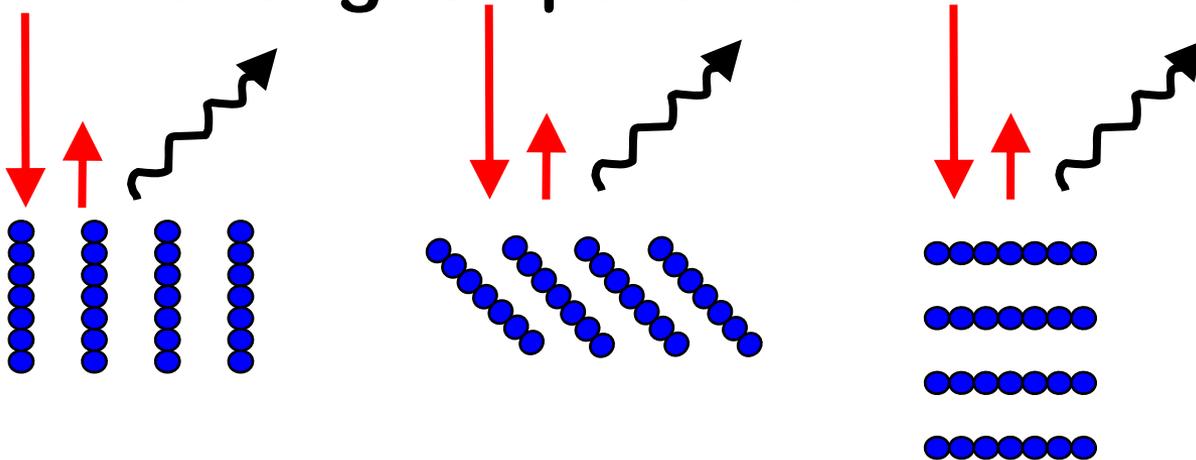
Example permeable curbs (Tempe Transit Center)

- Composite Designs

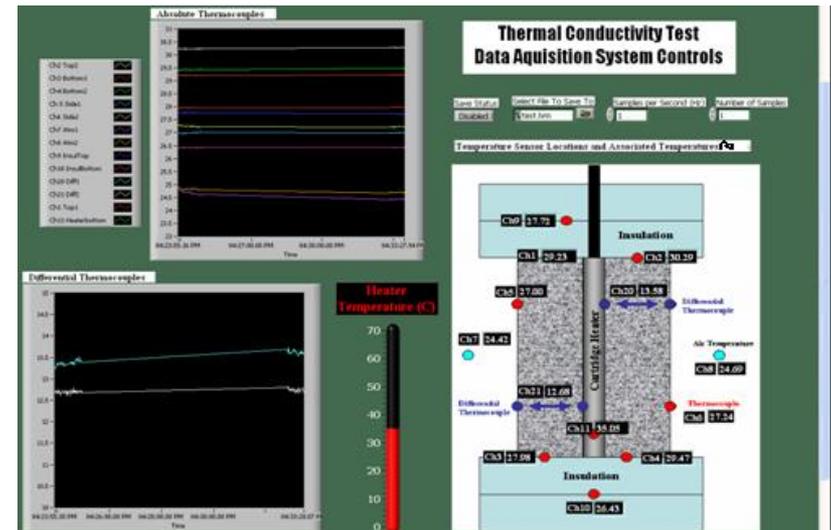
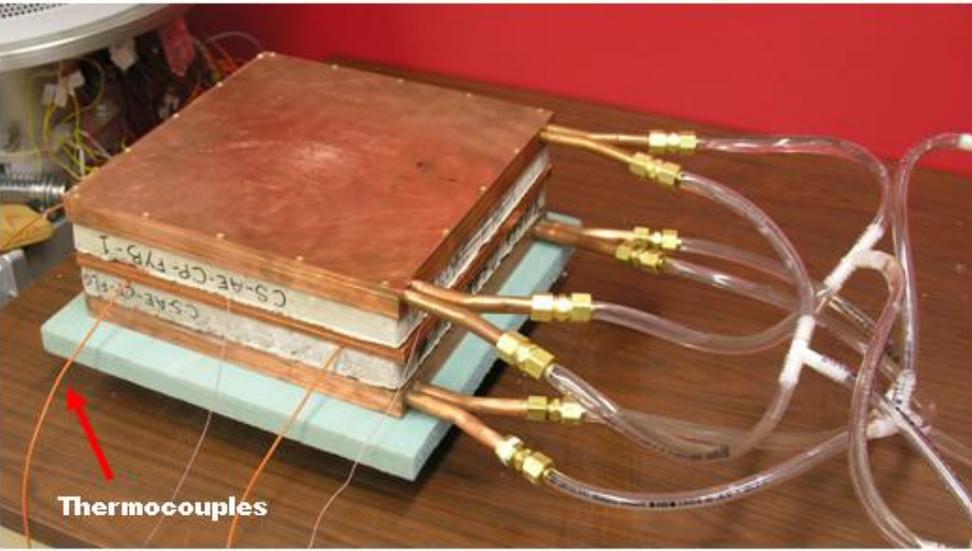




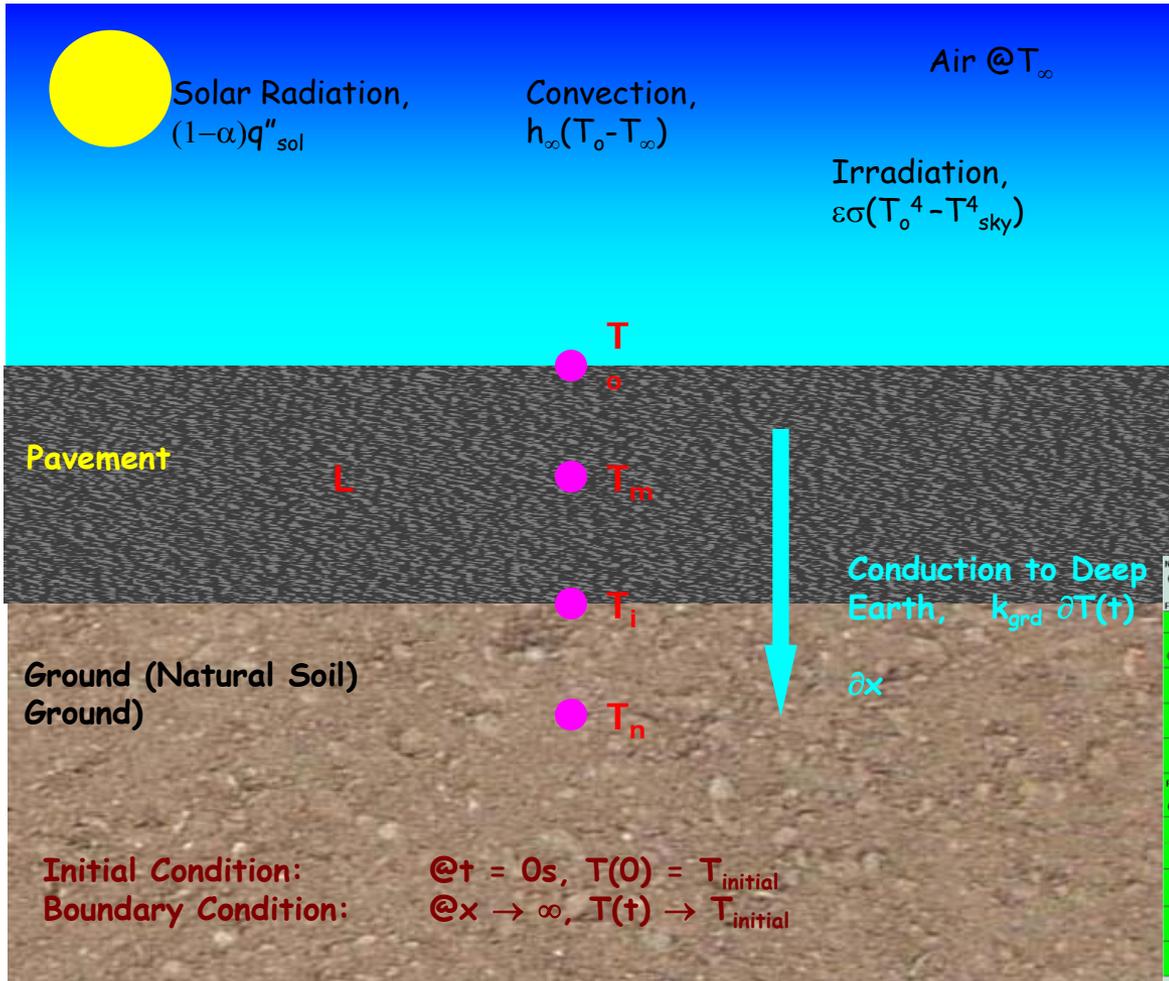
or aligned particles:



Laboratory Evaluation



Heat Transfer between Pavement and its Surroundings



- No. of Pavement Layers
- Density
- Specific Heat Capacity
- Thermal Conductivity
- Pavement Layer Thickness
- Pavement Layer Interface
- Thermal Contact Resistance
- Albedo of Top Layer
- Emissivity of Top Layer
- Deep Ground Properties
 - Temperature
 - Depth
- Sky View Factor
- Solar View Factor

Number of Layers of Pavement (inclusive of Ground) **3**

Fill in the Layers Properties in the following Table:

Layer S.N	1	2	3	4	5	REMARK
Material (I and Layer Ground)	PCC	Old HMA	Ground			OK
Density (kg/m ³)	2350	2238	1500			
SIC (JK/kgK)	1000	921	1900			
Conductivity (W/mK)	1.5000	1.2100	1.0000			
Pavement Thickness (m)	7.5	3.0				
Thermal Contact Resistance	0.1905	0.0762	0.0000	0.0000		
Albedo	Yes	Yes	No	No		
Interface Contact Resistance	0.0	0.0				
Albedo	0.46					
Emissivity	0.88					

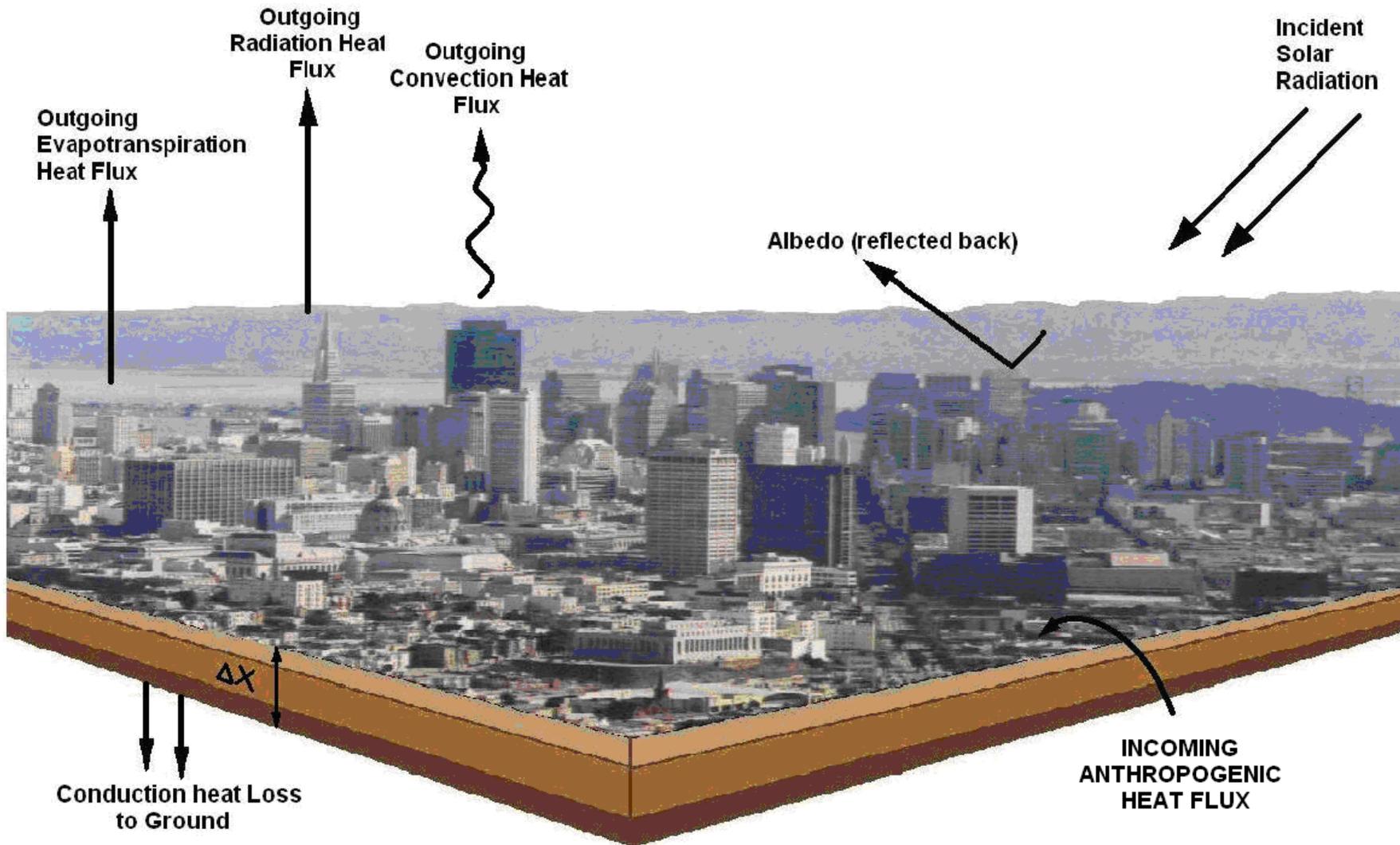
Deep Ground Properties:

i. Temperature **33.5** °C
ii. Depth of Ground Layer **3.0480** m

Sky View Factor **1.00**

Solar View Factor **1.00**

City – Wide Analysis



Concluding Remarks

- Pavements play a role in the urban heat island effect.
- There is no one solution that fits all!
- We need to appreciate the complexity of various designs and materials.
- More work needs to be done!

Thank You!



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