Pavements and the Urban Heat Island Effect

EPA's Cool Pavements Webcast
1/28/2010
2-3:30 EST

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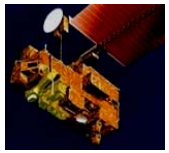
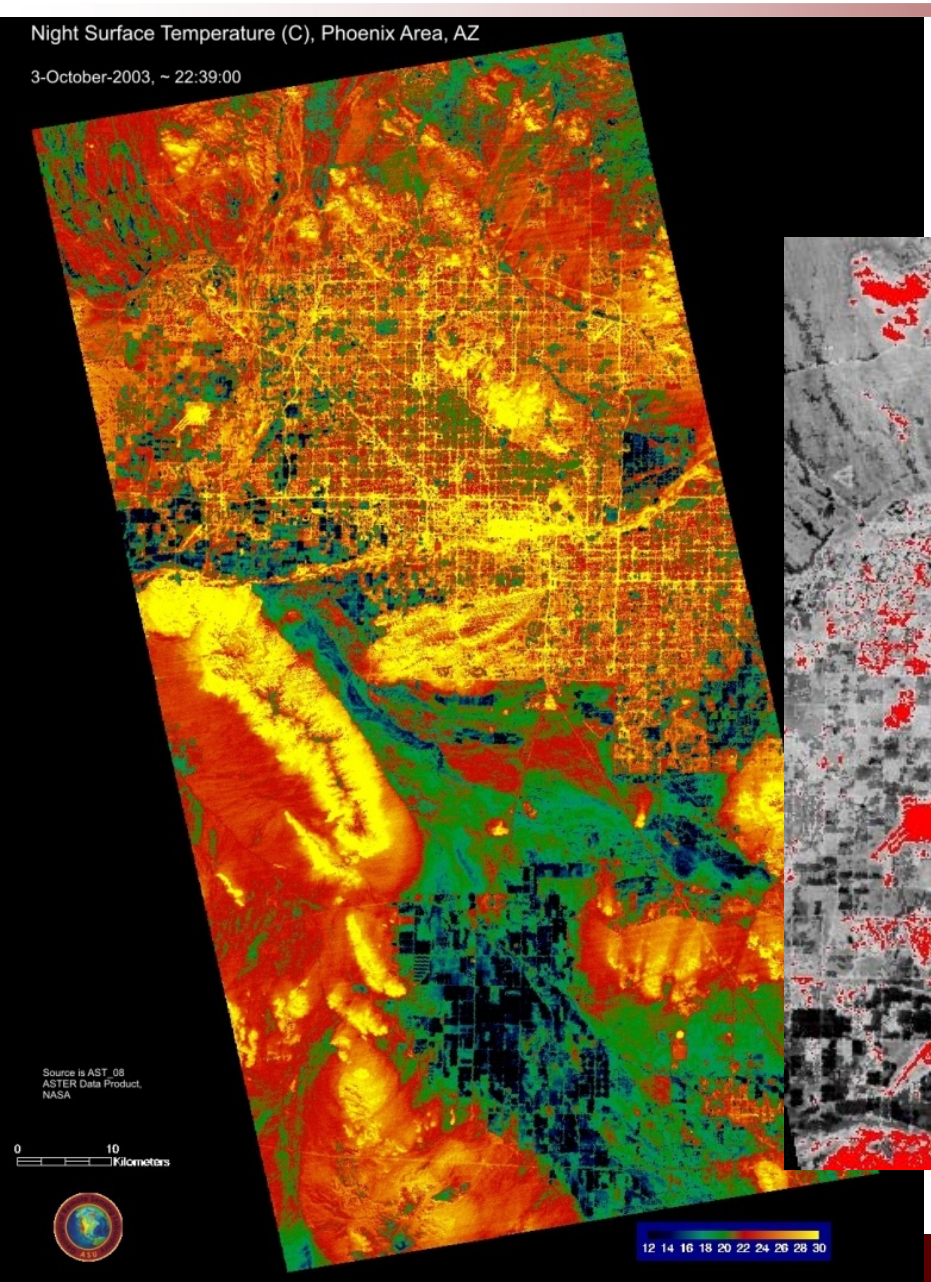
Do Pavements contribute to UHI?

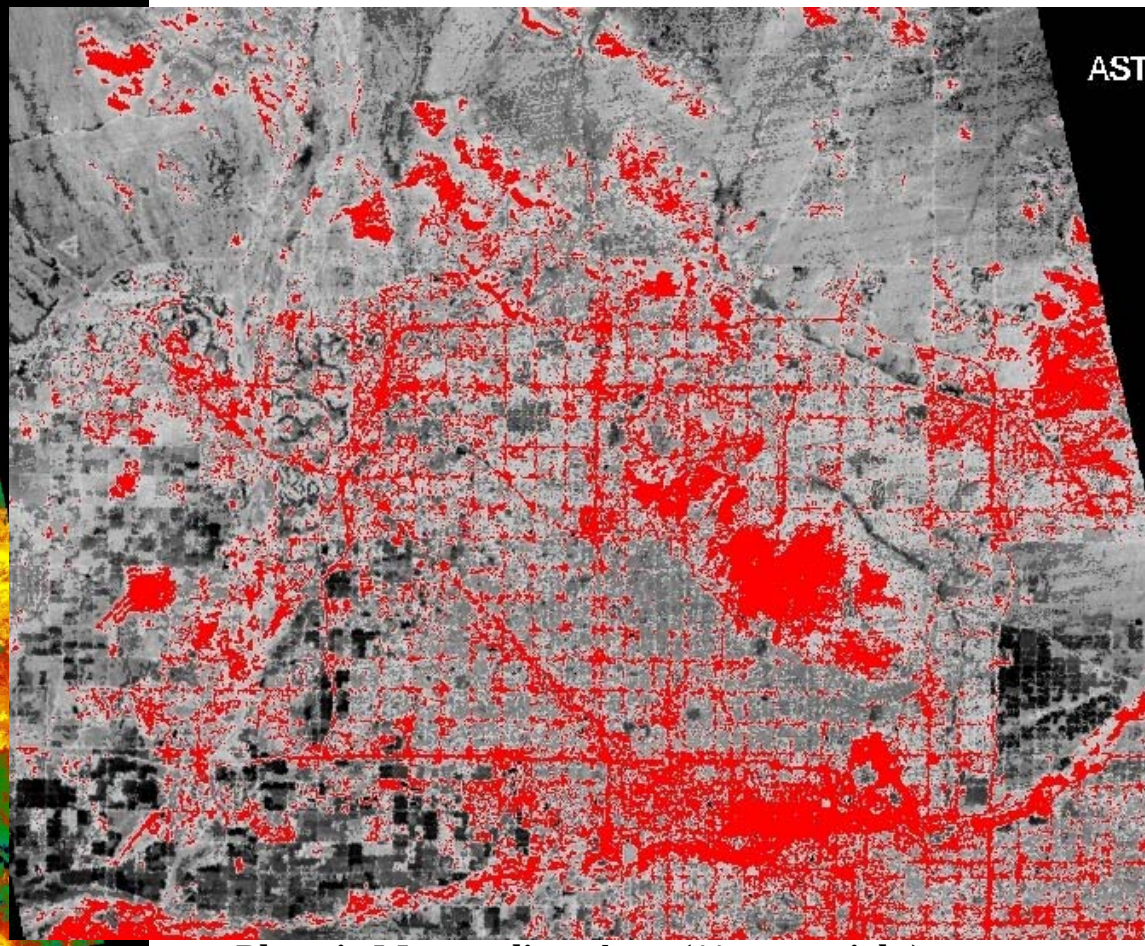
- If so:
  - How much and where?
- What are the:
  - evaluation techniques?
  - driving factors?
  - properties of materials?
  - design characteristics?
  - mitigation strategies and opportunities to pavements industries?
  - tools and models?



ASTER Satellite Imagery



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

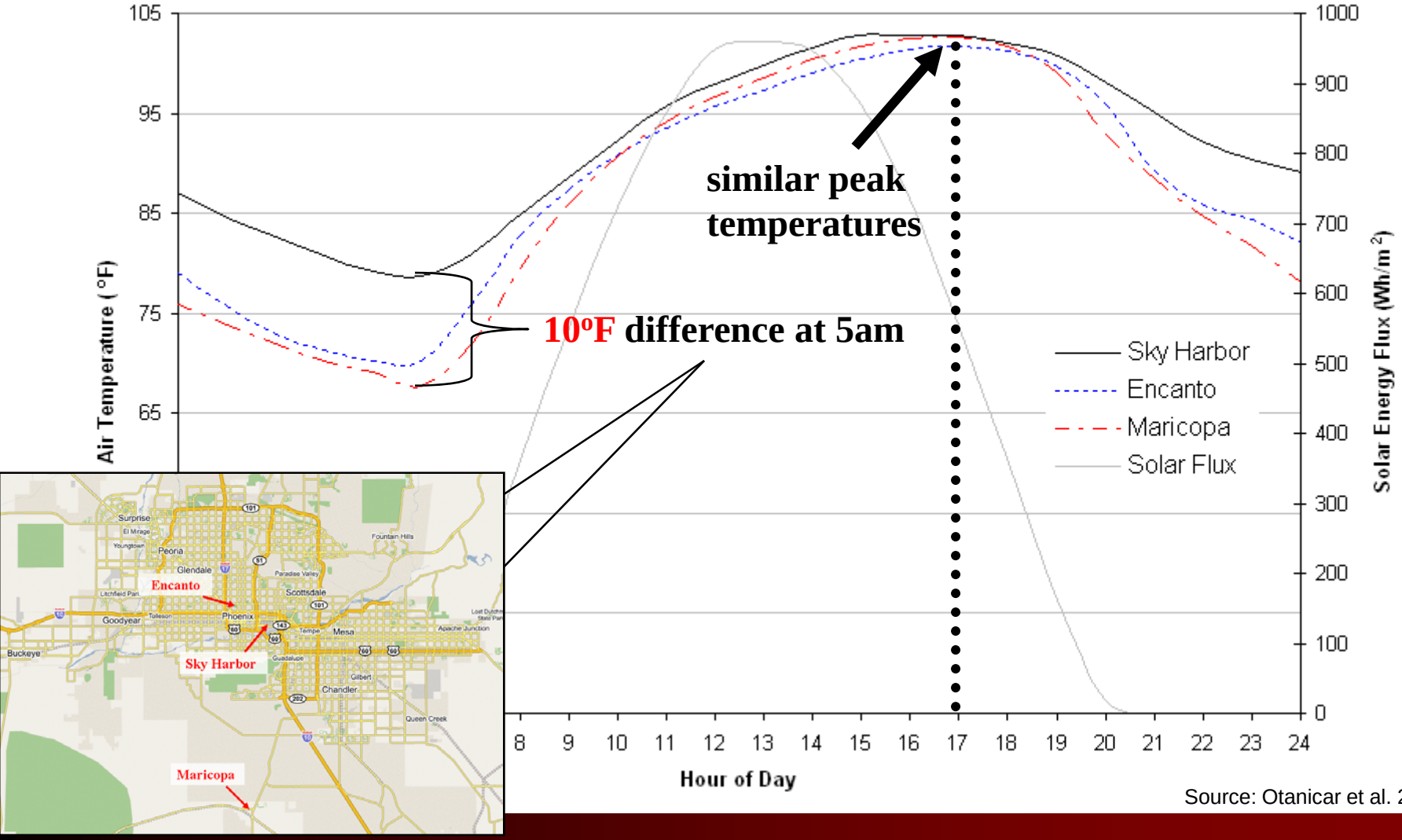


Phoenix Metropolitan Area (11pm at night)

How Much and Where?

Average Hourly Air Temperatures (July 2005)

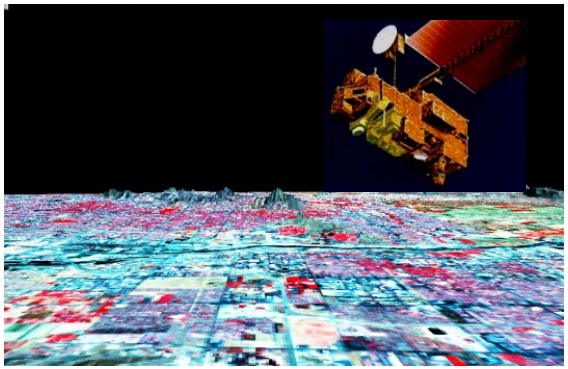
for Sky Harbor Airport (Urbanized), Encanto Park (Green Space), and the City of Maricopa (Rural)



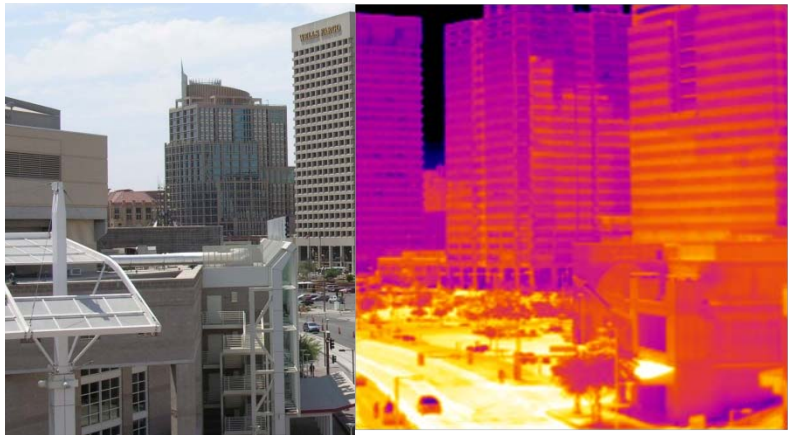
Source: Otanicar et al. 2007

UHI Evaluation Techniques

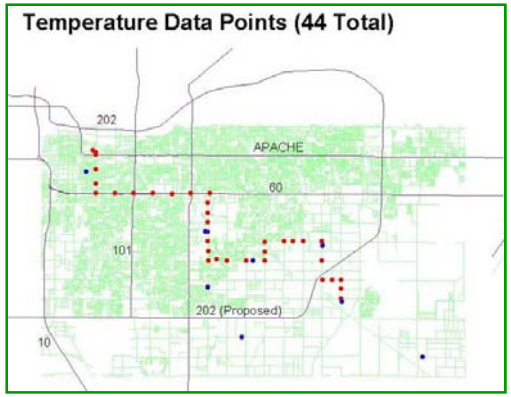
ASTER Thermal Imaging Satellite



IR Thermal Imagery

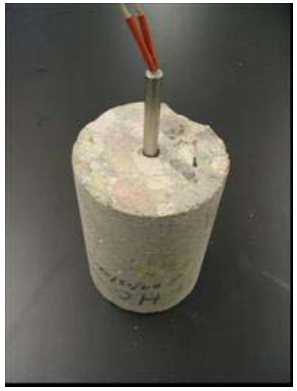


Mobile Transects

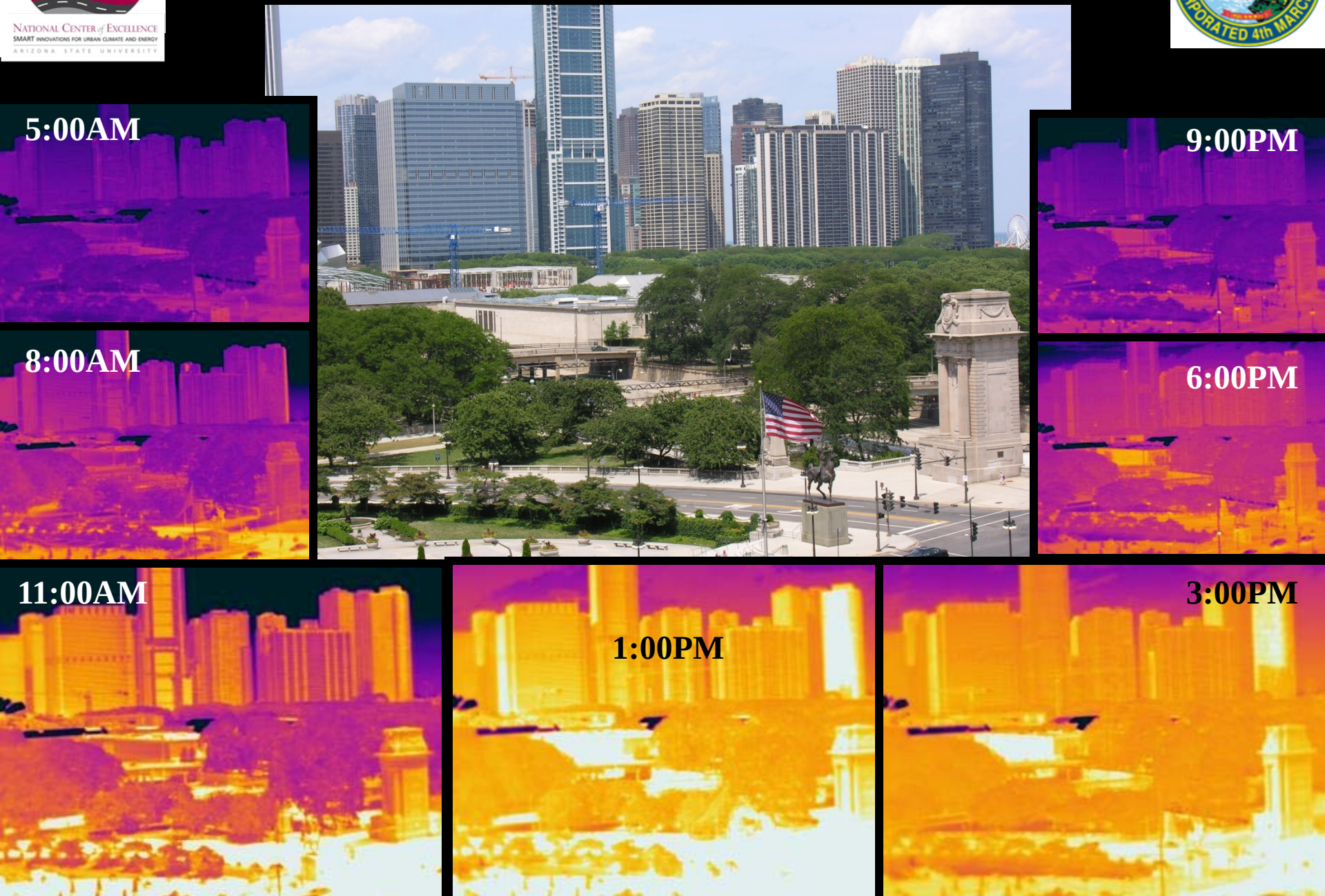


Embedded Thermocouples

Laboratory Testing

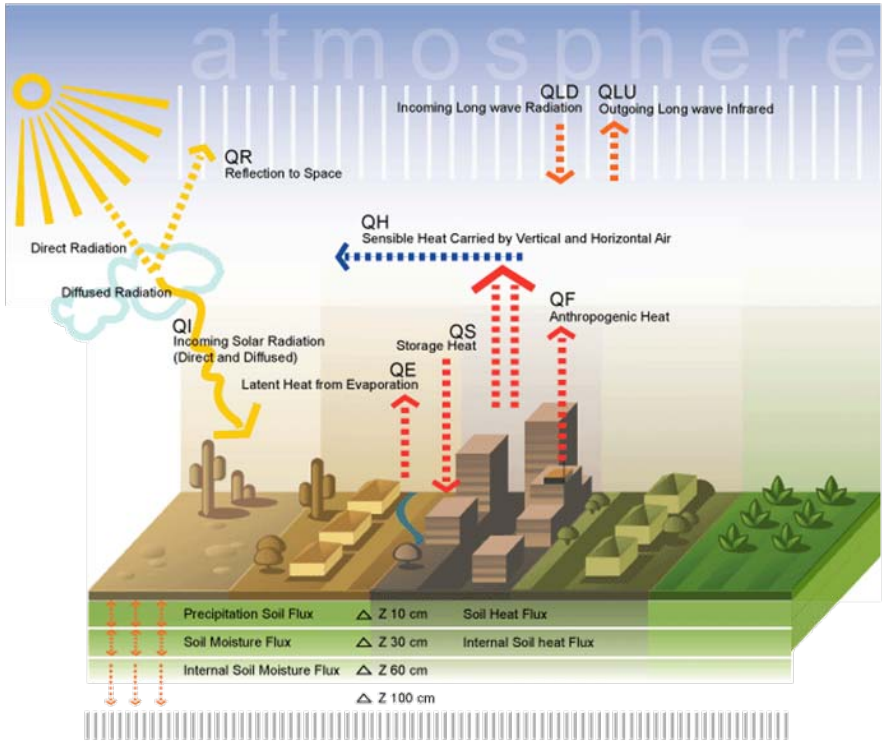


Time lapse infrared view of Chicago near Millennium Park
July 14 – 15, 2007



What are the driving factors?

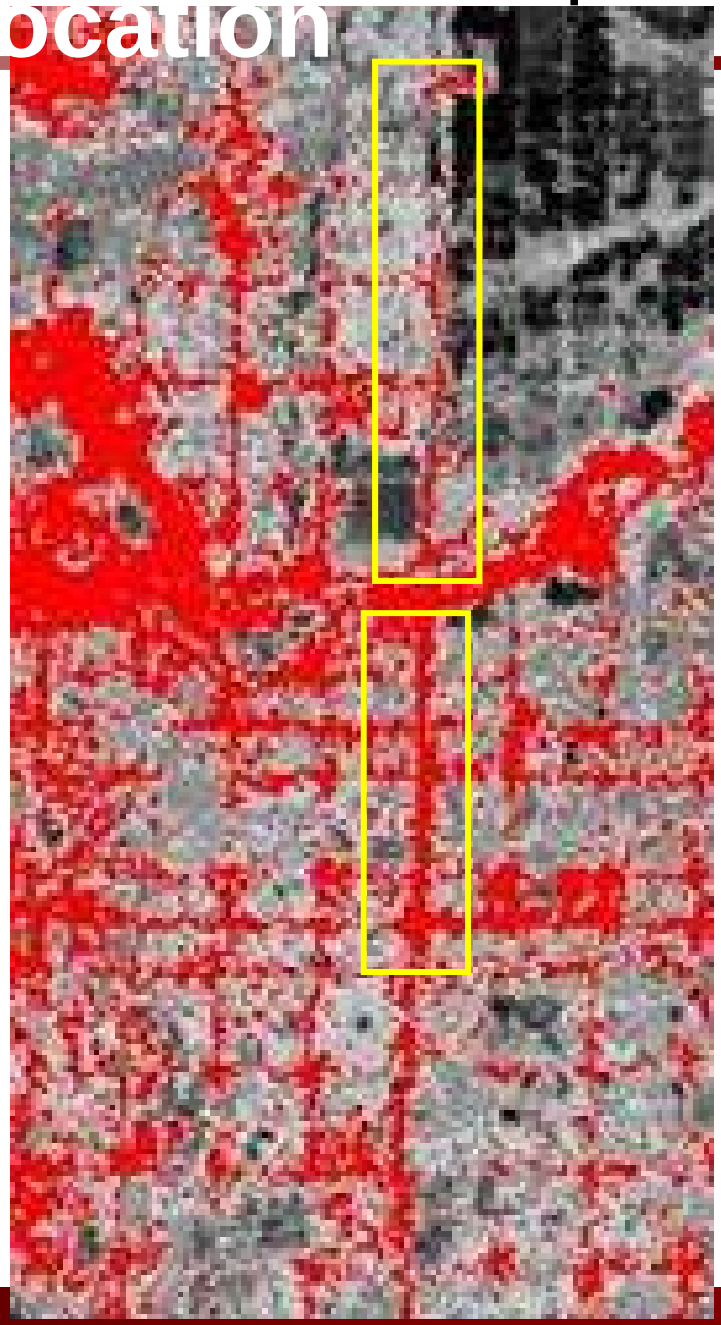
- ***Canyon Geometry***
- ***Thermal Properties***
- ***Anthropogenic Heat***
- ***The Urban Greenhouse Effect***
- ***The Effective Reflectivity (Albedo)***
- ***Reduction of Evaporating Surfaces***
- ***Reduced Turbulent Transfer of Heat***



■ Golden, Zehnder, Brazel 2004

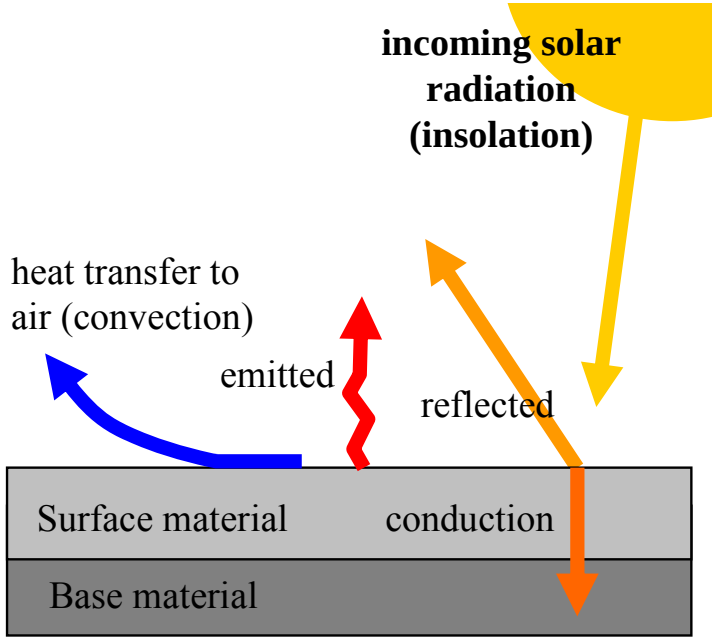
Oke et al. (1997)

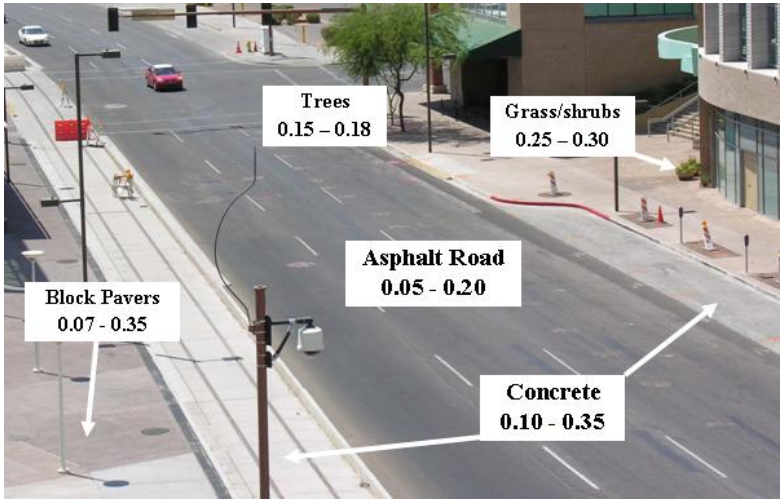
Example



Fundamental Properties

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

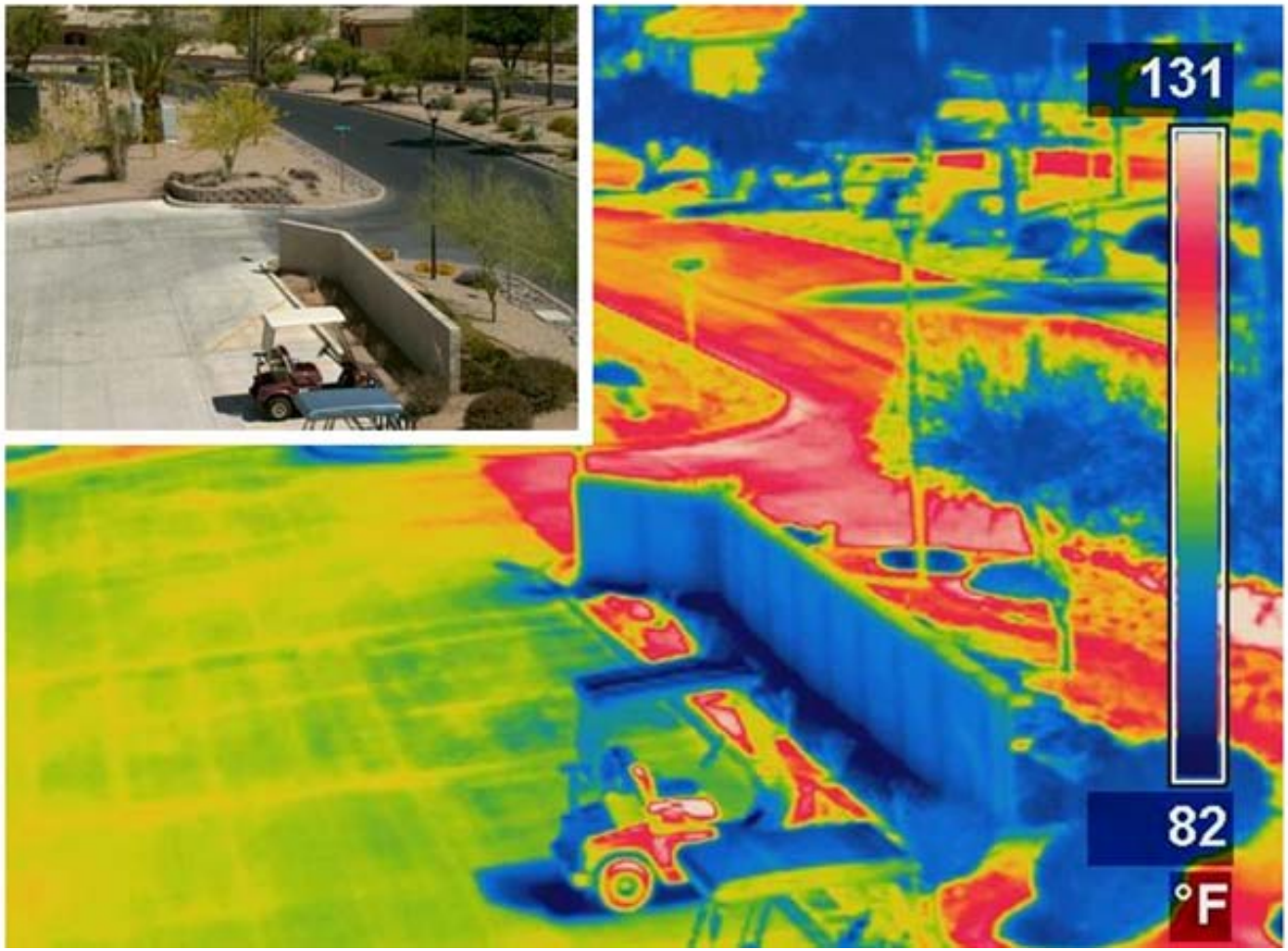




UHI Pavement Mitigation Strategies

- 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



Pavement Design Characteristics

Reflective Asphalt Pavements

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

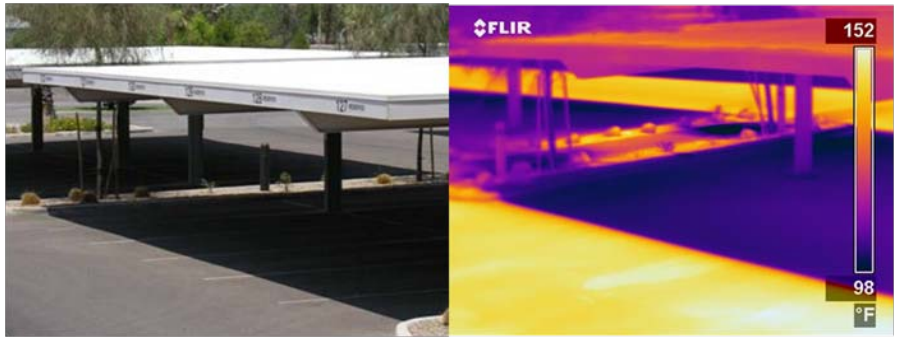
"Gritting":
reflective chips and aggregate

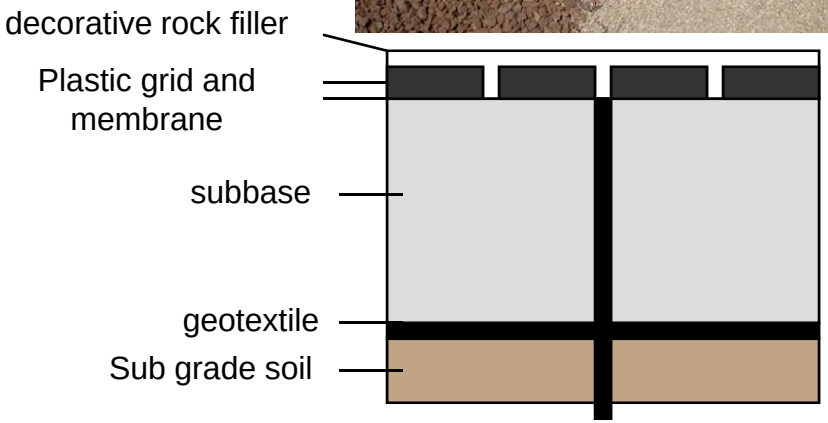
Shot-Blasting:
abrading surface binder

Pervious / Porous Parking Lots

Other ?

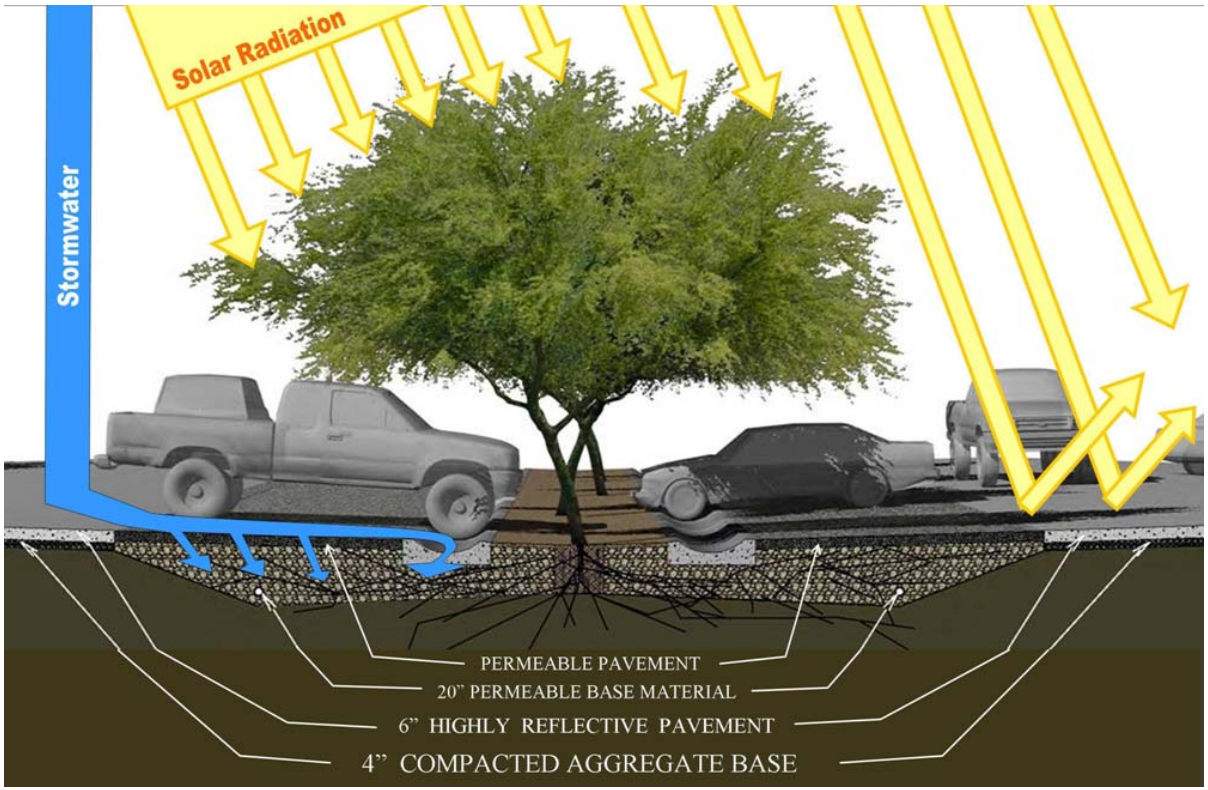
U-haul : Permeable Pavement





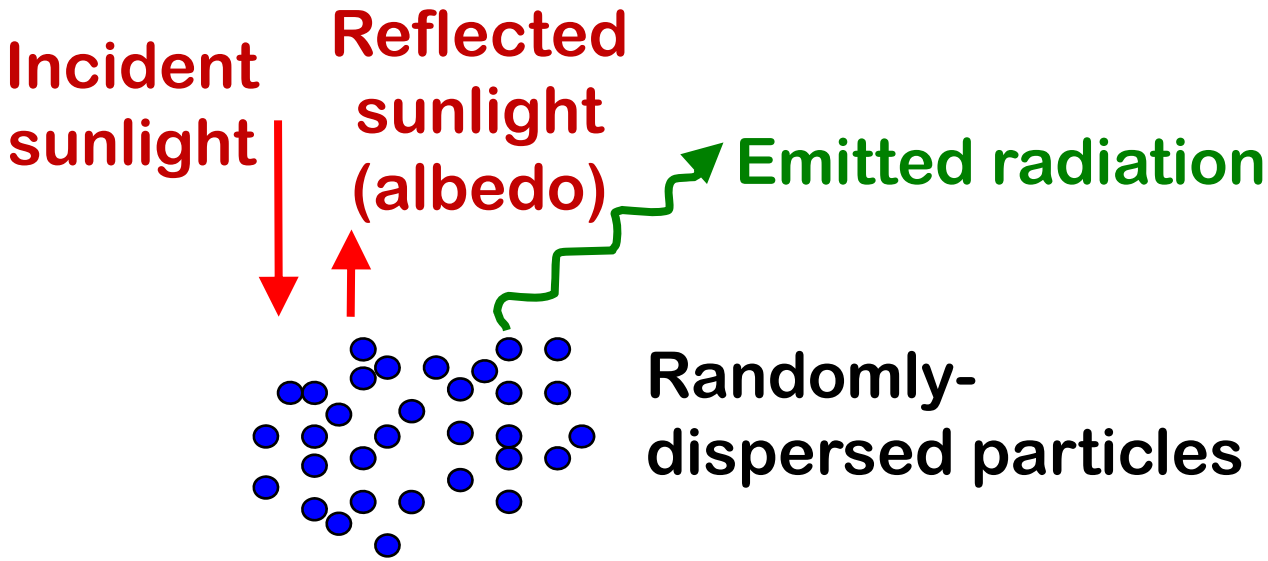
Hybrid Designs

- Composite Designs

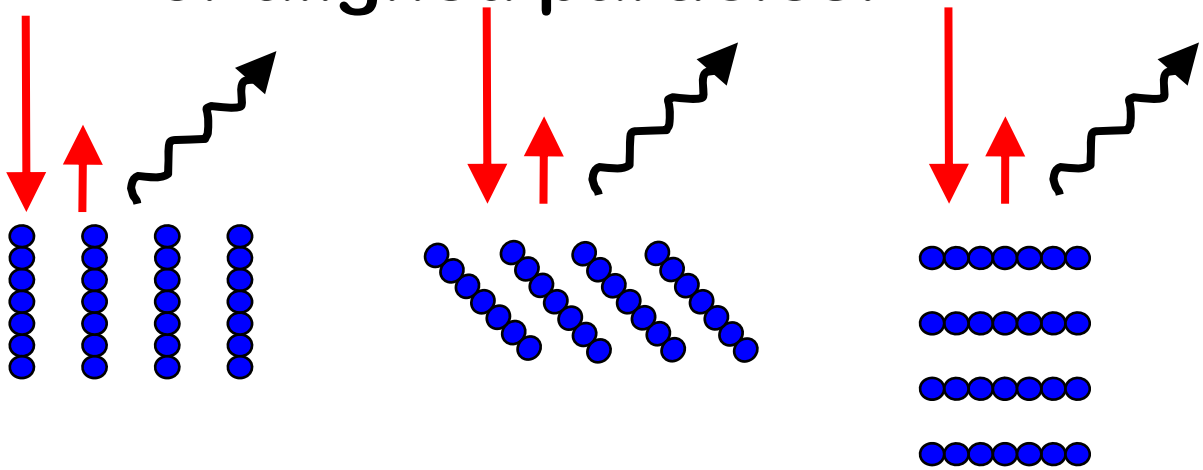


Example permeable curbs (Tempe Transit Center)

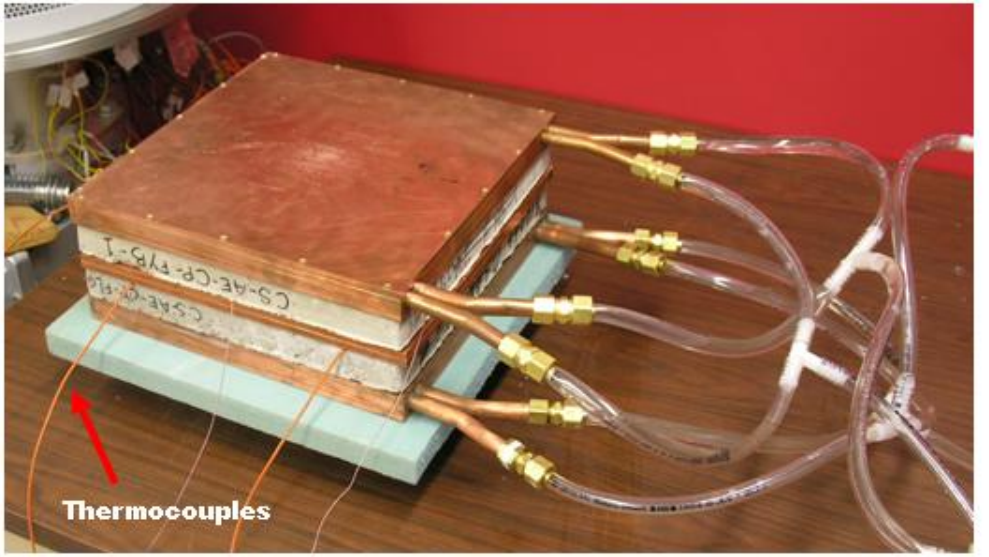
Modifying Radiative Properties

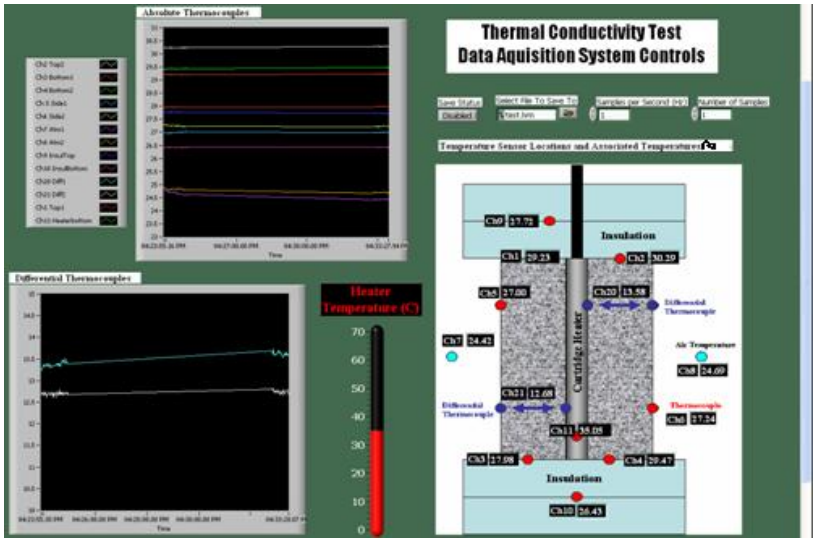


or aligned particles:



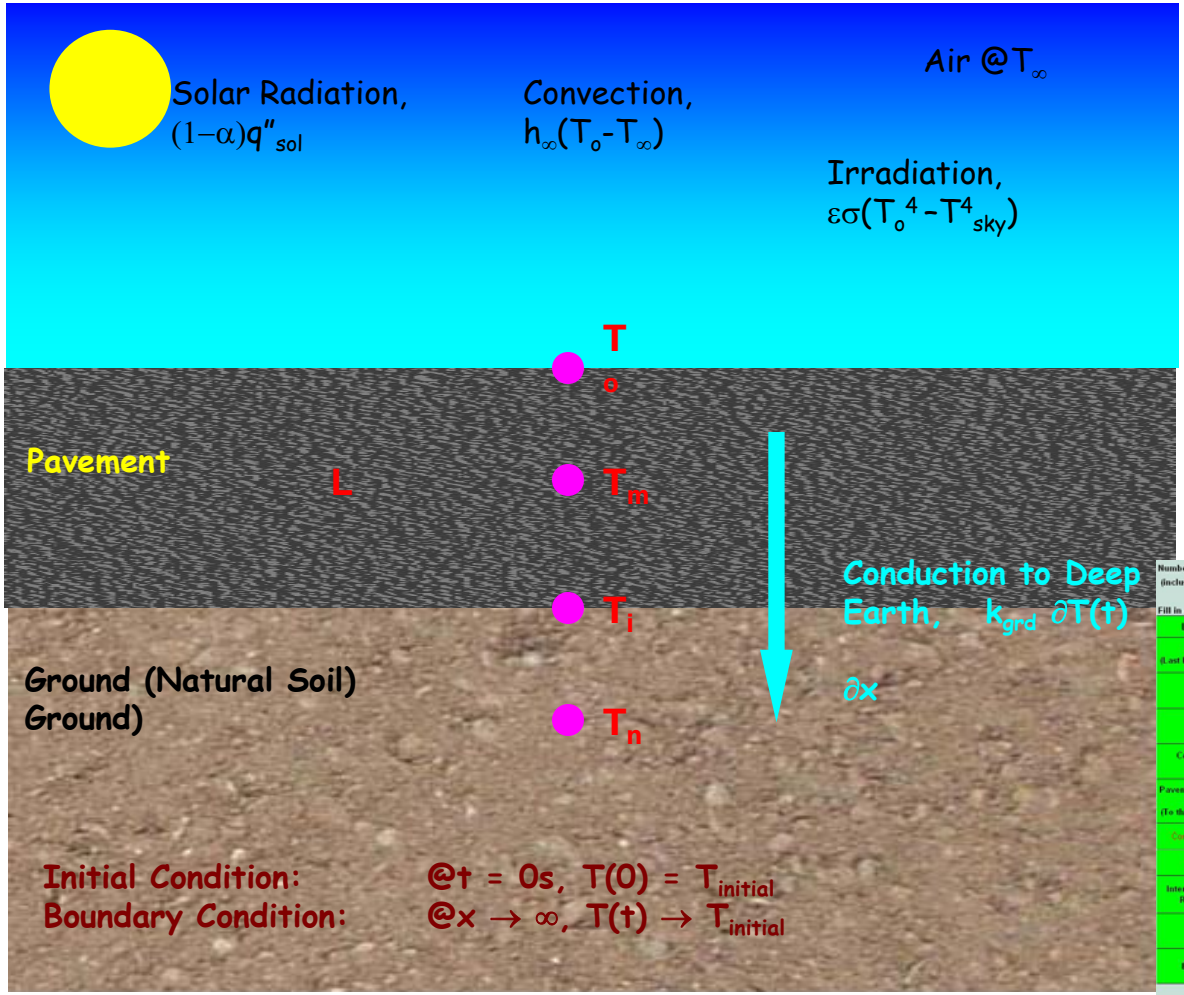
Laboratory Evaluation



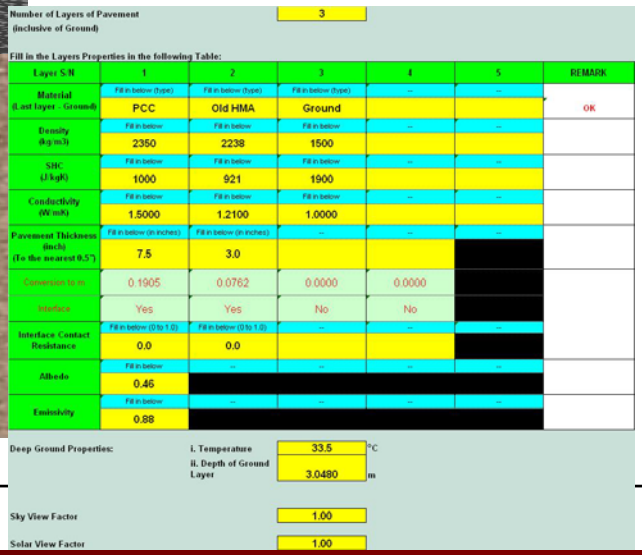


Tools - Models

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:

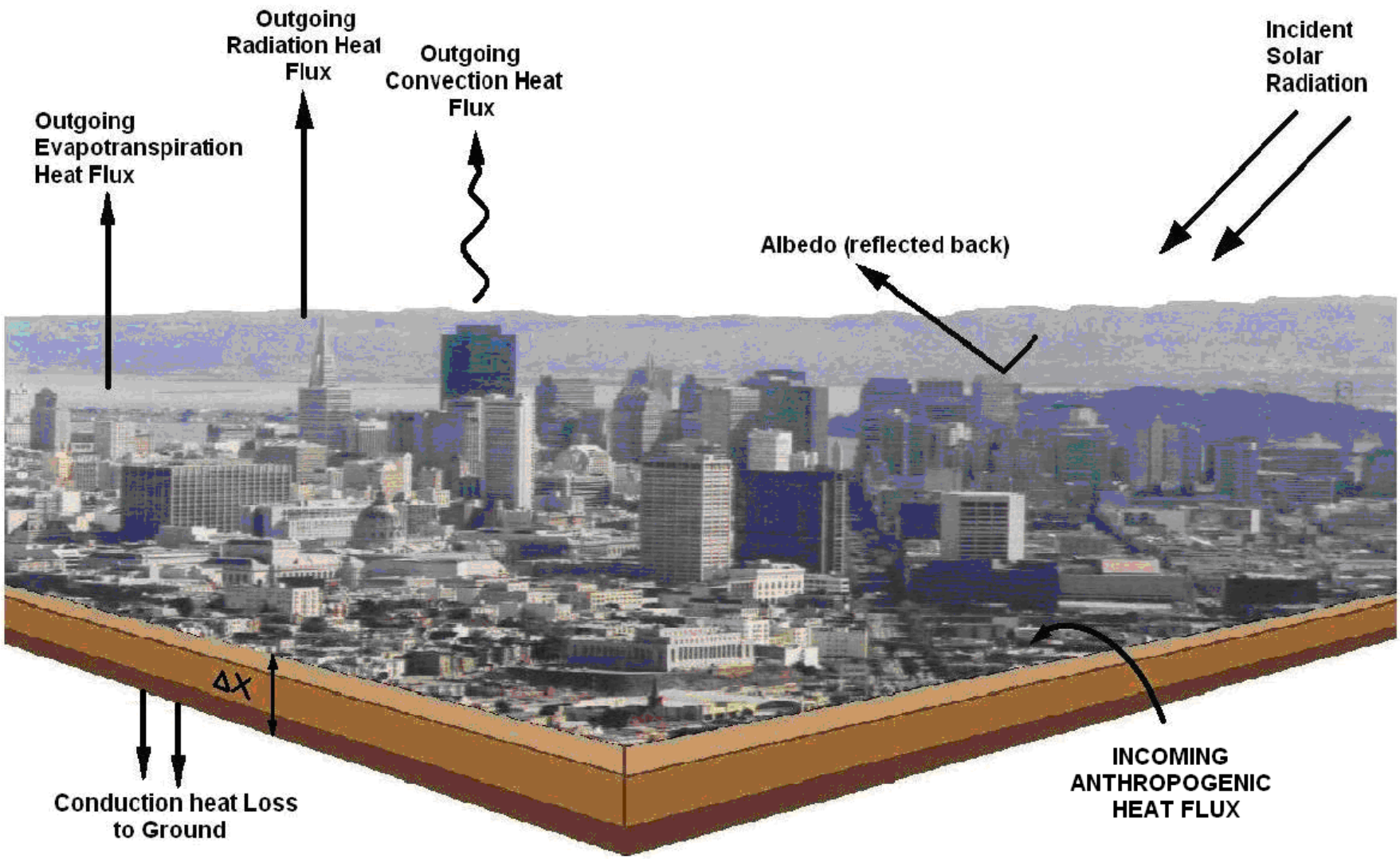
Layer S.N	1	2	3	4	5	REMARK
Material (Last layer - Ground)	Fill in below (type): PCC	Fill in below (type): Old HMA	Fill in below (type): Ground	--	--	OK
Density (kg/m3)	Fill in below: 2350	Fill in below: 2238	Fill in below: 1500	--	--	
SHC (J/kgK)	Fill in below: 1000	Fill in below: 921	Fill in below: 1900	--	--	
Conductivity (W/mK)	Fill in below: 1.5000	Fill in below: 1.2100	Fill in below: 1.0000	--	--	
Pavement Thickness (inch) (To the nearest 0.5")	Fill in below (in inches): 7.5	Fill in below (in inches): 3.0	--	--	--	
Conversion to m	0.1905	0.0762	0.0000	0.0000		
Interface	Yes	Yes	No	No		
Interface Contact Resistance	Fill in below (0 to 1.0): 0.0	Fill in below (0 to 1.0): 0.0	--	--	--	
Albedo	Fill in below: 0.46	--	--	--	--	
Emissivity	Fill in below: 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!

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Thank You!

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