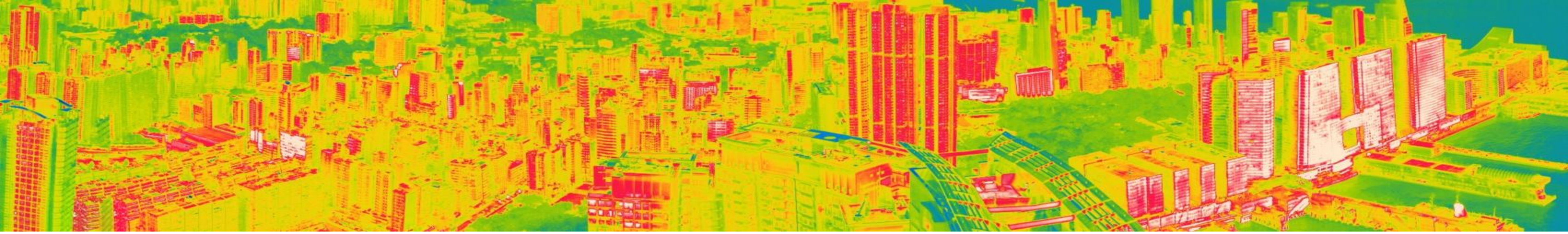

Impact of Urban Morphology on Average Urban Albedo

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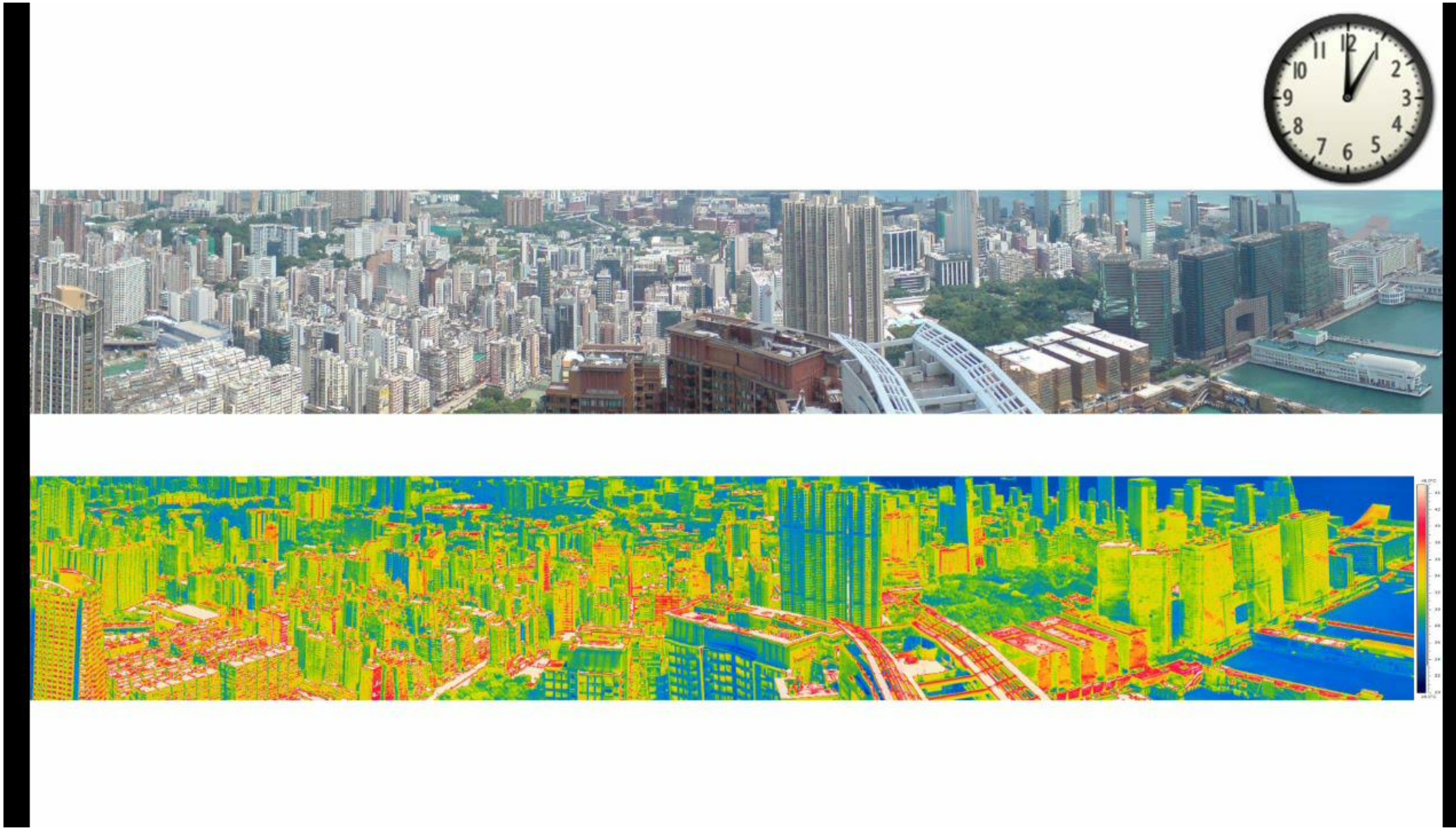
Infrared imaging of Kowloon to studying the impact of thermal properties of built structure materials



From ICC building, Hong Kong on 13th Sep, 2010

Developing a 3D solar radiation model

solar radiation on a plan surface

Direct solar radiation

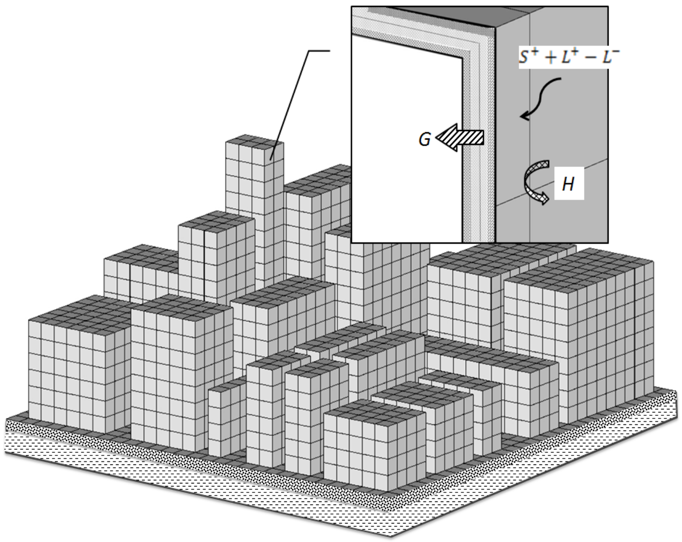
$$I_{dr} = I_{sc} E_0 P_{at}^{1/\sin\theta_a} \cos\theta_{in}$$

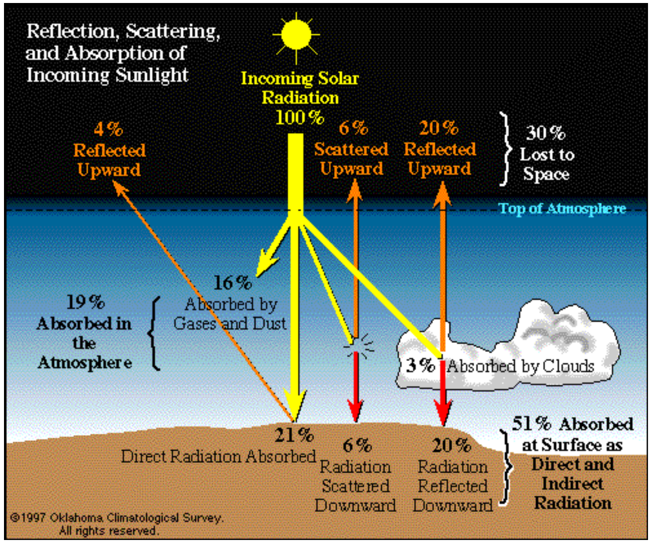
Diffuse solar radiation

$$I_{df} = 0.5 F_{is} I_{sc} \sin\theta_a \frac{1 - P_{at}^{1/\sin\theta_a}}{1 - 1.4 \ln P_{at}}$$

I_0 - solar constant
E_0 - eccentricity correction
P_{at} - the atmosphere transparency
F_{is} - sky view factor of the surface
θ_α - solar altitude
θ_{in} - solar incidence angle

$$S^+ = (1 - \alpha^s)(I_{dr} + I_{df}) + \sum_{j=1}^{N} G_{ji}^S q_j^S$$





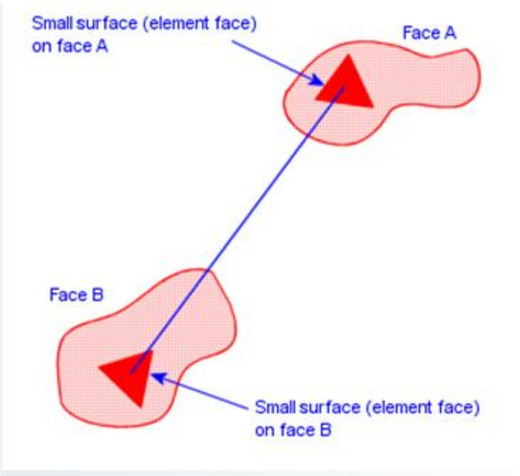
The DTM method is adopted for calculating shape factor

Fraction of energy leaving black surface element *A* that arrives at black elements *B*

Discrete transfer method (Shah, 1979)

➢It is based on the concept of tracking the representatively directed radiation rays

$$F_{ij} = \frac{Q_{ij}}{Q} = \frac{A_j \sum \cos\theta_i \sin\theta_i (\sin\Delta\theta)\Delta\phi}{\pi A_i}$$

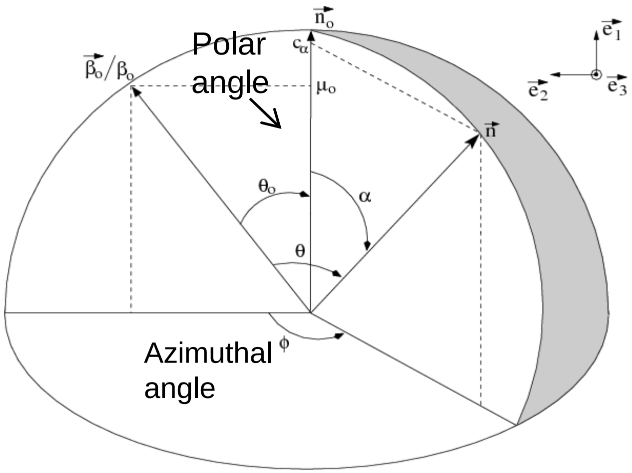


➢It is also used to determine the sunlit-shaded distributions

Gebhart absorption factor (Gebhart, 1971)

It provides the percentage of energy emitted by a surface that is absorbed by another surface after reaching the absorbing surface by all possible paths

$$G_{ij}^{\lambda} = F_{ij}\zeta_j^{\lambda} + \sum_{k=1}^{N} G_{kj}^{\lambda}\rho_k^{\lambda}F_{ik}$$

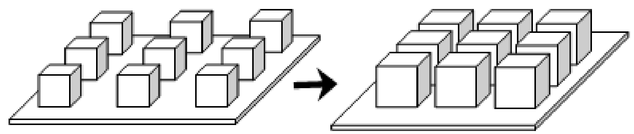


$$N_{DTM} = N_\theta N_\phi \quad \Delta\phi = \frac{2\pi}{N_\phi} \quad \Delta\theta = \frac{\pi}{2N_\theta}$$

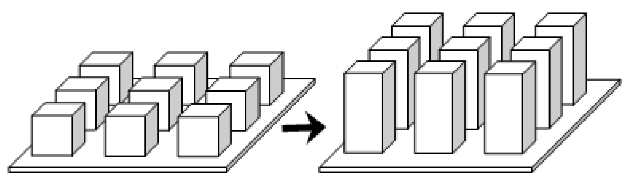
Average urban albedo

$$\alpha_r = 1 - \frac{\sum_{k=0}^{24}\left[\sum_{i=1}^{N}\left((1-\alpha_i)I_{dir,i,k}S_i + (1-\beta_i)I_{dif,i,k}S_i + \sum_{j=1}^{N}G_{ji}(\alpha_j I_{dir,j,k} + \beta_j I_{dif,j,k})S_j\right)\right]}{\sum_{k=0}^{24}\left[\sum_{i=1}^{N}(I_{dir,i,k} + I_{dif,i,k})S_i\right]}$$

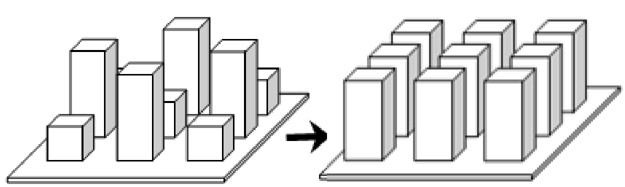
Scenario A: Building density ($H/L = 1$)

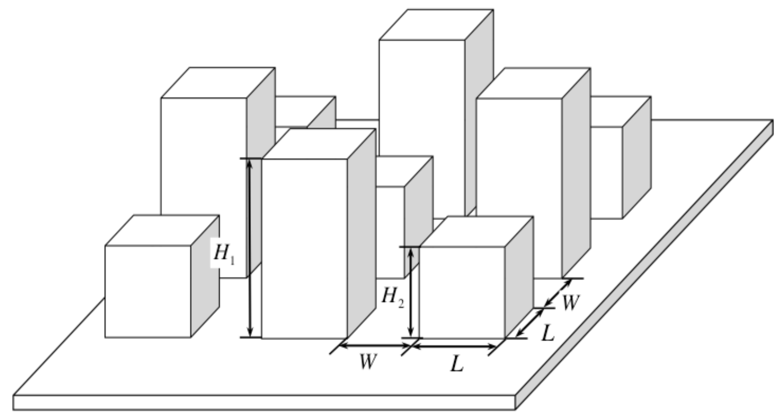
No.	Plan area	Sketch map
A1 ~ A5	0 ~ 0.79	

Scenario B: Building height ($\lambda_p = 0.44$)

No.	H/W	Sketch map
B1 ~ B6	1 ~ 6	

Scenario C: Building stagger arrangement ($\lambda_p = 0.44$, $H_1/W = 6$)

No.	H_1/H_2	Sketch map
C1 ~ C6	6:1 ~ 6:6	

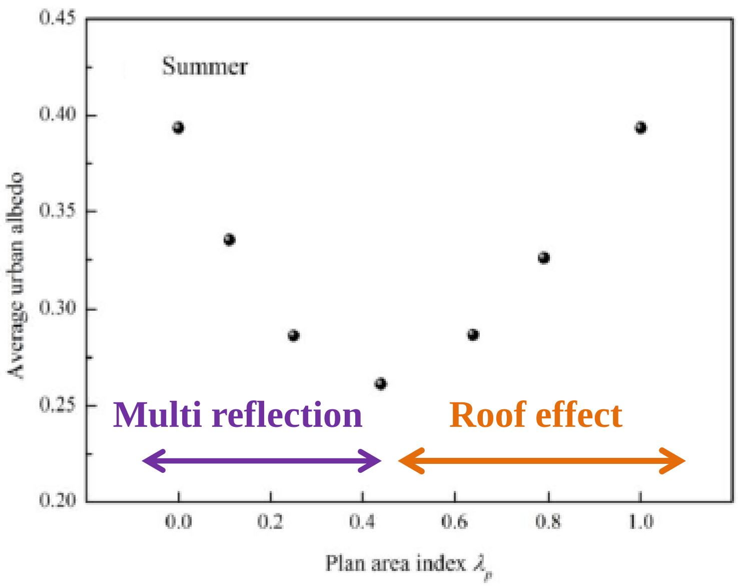


Study days:

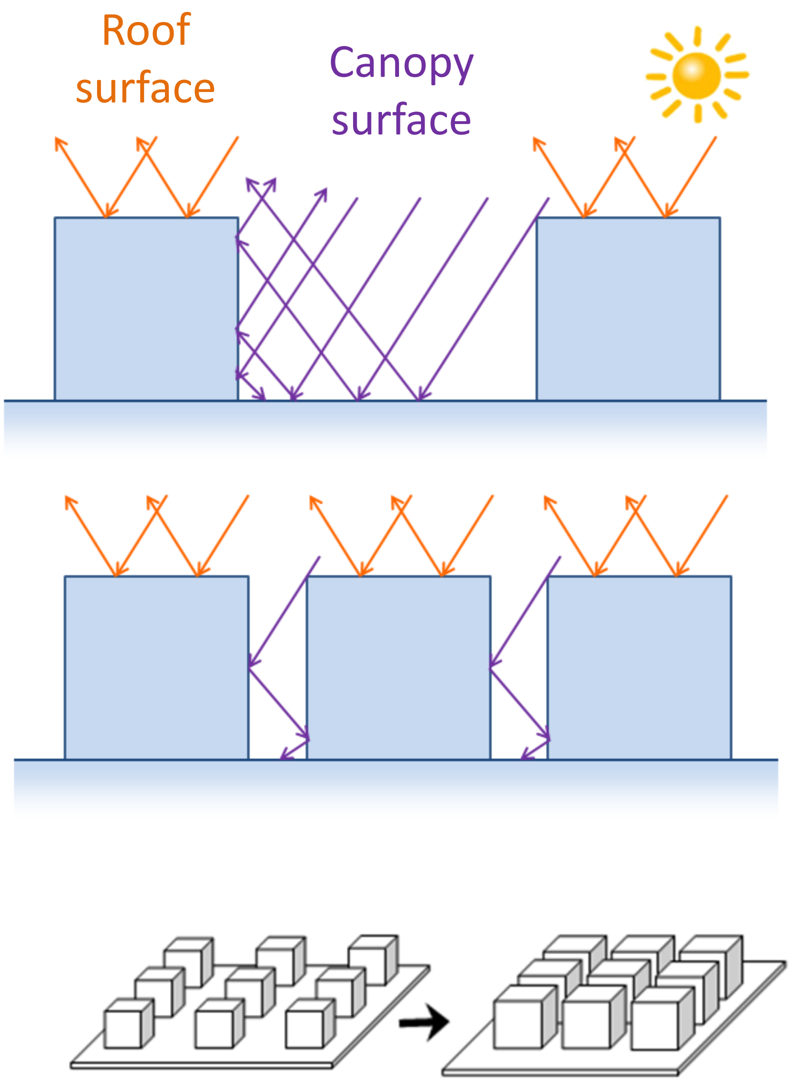
Summer: 31 Jul 2012

Winter: 21 Dec 2012

Scenario A - Building density ($H / L = 1$, *plan area index* $\lambda_p \sim 0 - 0.79$)

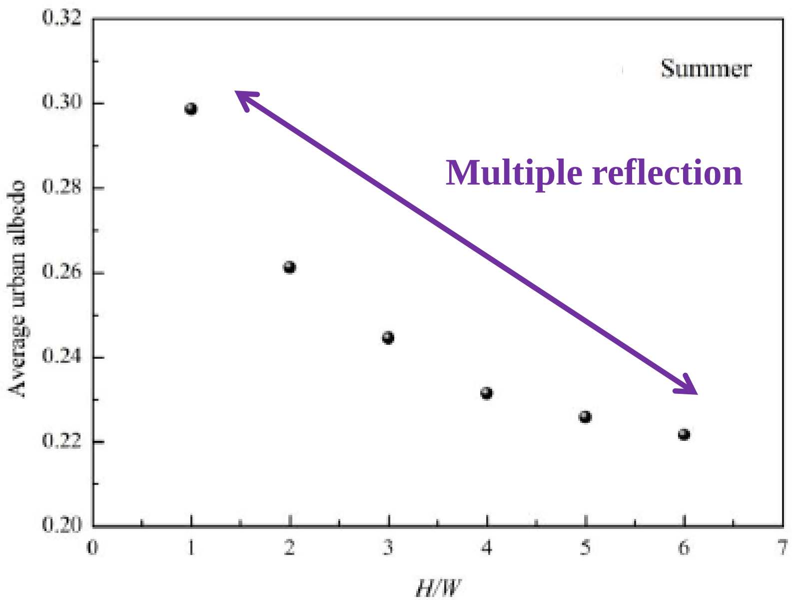


Relationship between the average urban albedo and the plan area index

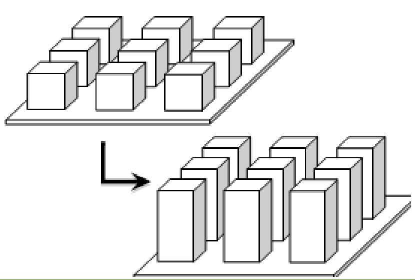


- **Most incoming solar radiation is received by the street level for plan area index smaller than 0.5.**
- **Most incoming heat will be reflected by the roof for compact urban area.**

Scenario B - Building height (plan area index λ_p = 0.44, H / W ~ 1 - 6)



Relationship between the average urban albedo and the *H/W* ratio

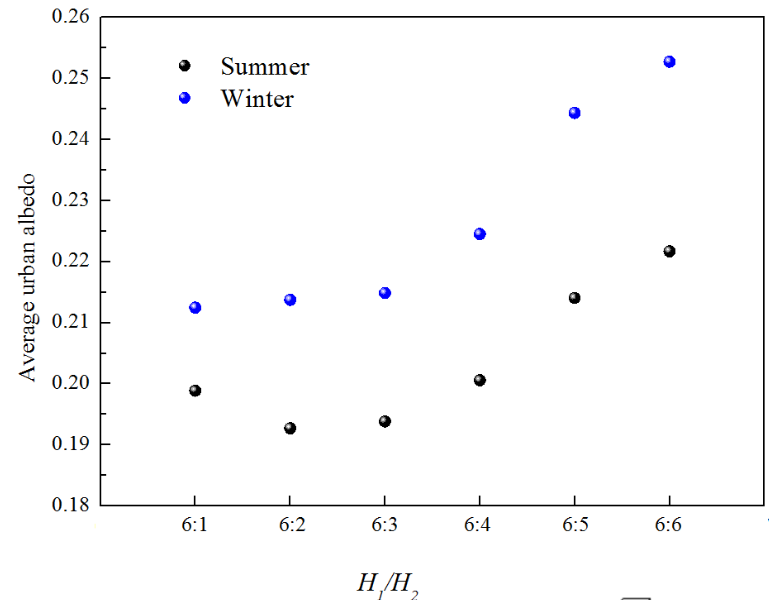


Roof effect:
always able to reflect incoming reflection

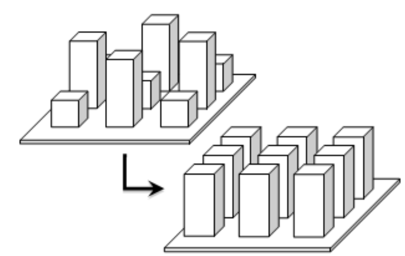
The higher the city, the lower the reflection – but there is a limit

Scenario C - Building stagger arrangement (plan area index λ_p= 0.44, H_1 / W = 6 and H_1:H_2 ~ 6:1 – 6:6 with H_2 varies)

Relationship between the average urban albedo and the abnormity extent (H_1/H_2)



Roof surface for lower height building always involve in multiple reflection process



Solar heat reflection increase with building height getting uniformity

Conclusions

- Both the surfaces of street level and the roof surfaces may play a dominant role in the radiation reflection process
- The higher the city, the lower the reflection – but there is a limit
- Solar heat reflection increase with building height getting uniformity
- The average urban albedo is less for a moderately compact (λ_p =0.44) city having high rise buildings with varying building heights than other cases

Thank you!