



Computational and Information Sciences Directorate

Battlefield Environment Division

# A Model for Nighttime Urban Illumination

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# Outline



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**Why is such a model needed?**

**Current state of models**

**New model: Light, Urban Model Effects (LUME)**

**Urban lighting databases**



# Why?



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The Army has the capability to operate 24/7

- The use of Electro-Optic (EO) sensors offers a passive solution to night operations
  - II/NVGs: 0.6 – 0.9  $\mu\text{m}$
  - FLIRs: 8 – 12/14  $\mu\text{m}$  or 3 – 5  $\mu\text{m}$
- Brightly lit areas may saturate NVGs, causing them to 'gain down' effectively blinding the wearer
- Single street lights frequently produce a 'halo' leading to a loss of contrast



# SOURCES OF NIGHT ILLUMINATION



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- **Residual Sunlight**
- **Moonlight**
  - **New**
    - very low light levels
  - **First Quarter**
    - relatively good light levels
  - **Full**
    - very high light levels
  - **Third Quarter**
    - relatively good light levels
- **Moonless**
  - **Starlight: 25 to 30%**
  - **Airglow 40%**
  - **Remainder aurora, luminous patterns of light**



# Urban lighting



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- **Affects target acquisition**
  - **differing contrasts**
- **Reflected light can provide significant illumination**
  - **clouds**
- **cultural lighting varies significantly**



# Urban lighting



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- **Lighting**
  - **Types**
  - **Fixtures**
- **Ground reflections**
- **Buildings**
  - **BRDF**
  - **windows**



# Atmosphere

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- **Effects**
  - **Scattering**
  - **Absorption**
  - **Refraction**
- **Aerosols**
  - **Clouds**
  - **Fog**
  - **Rain**
  - **Snow**
  - **Battlefield obscuration**



# Current Models

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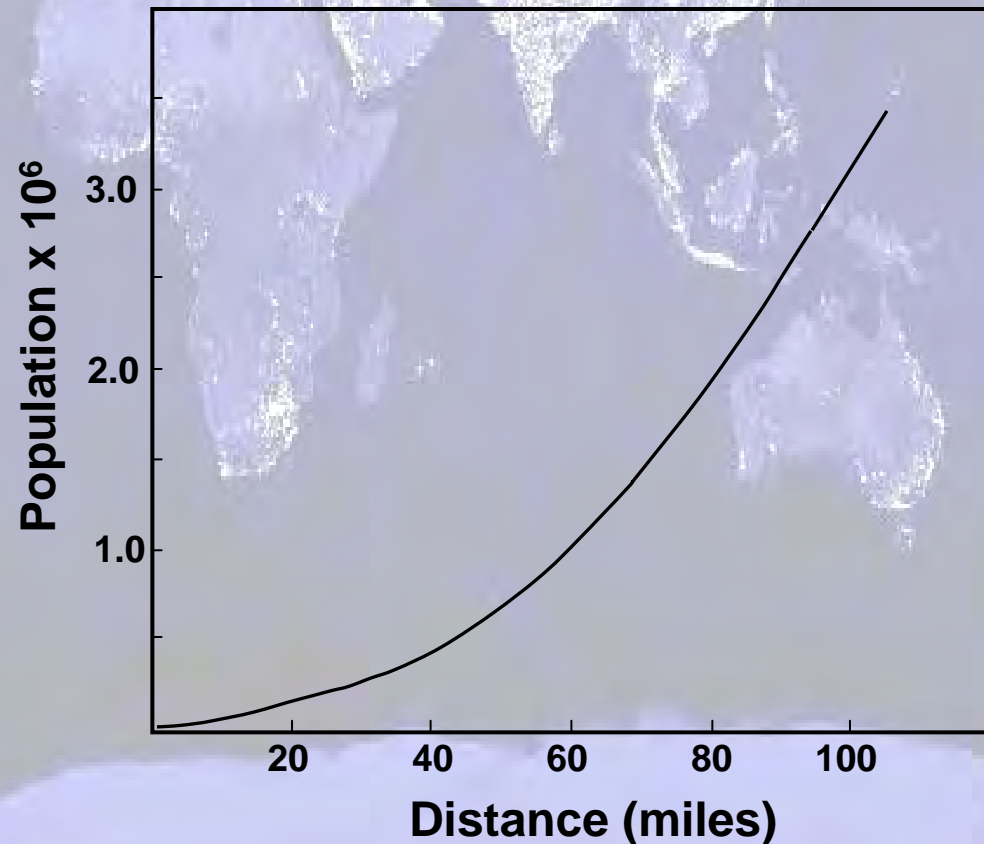
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## Astronomers

Walker:  $P \propto D^{2.5}$

Garstang:  $I = C P D^\alpha$

where  $C$  and  $\alpha$  are  
constants:  $\alpha \approx 2.5$





# Garstang's Model



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- **City is a disk (not a point source)**
- **Non-homogeneous atmosphere (exponential)**
- **Rough ability to include aerosols**
- **Ground reflection included**
- **Night sky background included**
- **Curved earth accounted for**



# Garstang Brightness Distribution



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$$\begin{aligned} B = & \pi N_m \sigma_R \exp(-ch) \iint (dx dy / \pi R^2) \\ & \times \int_0^x I_{xy} s^{-2} (EF)_{xQ} (EF)_{QO} (DS) \\ & \times \{ \exp(-ch) 3(1 + \cos^2 \Theta) / (16\pi) \\ & + \exp(-ah) 11.11 K f(\Theta) \} du \end{aligned}$$



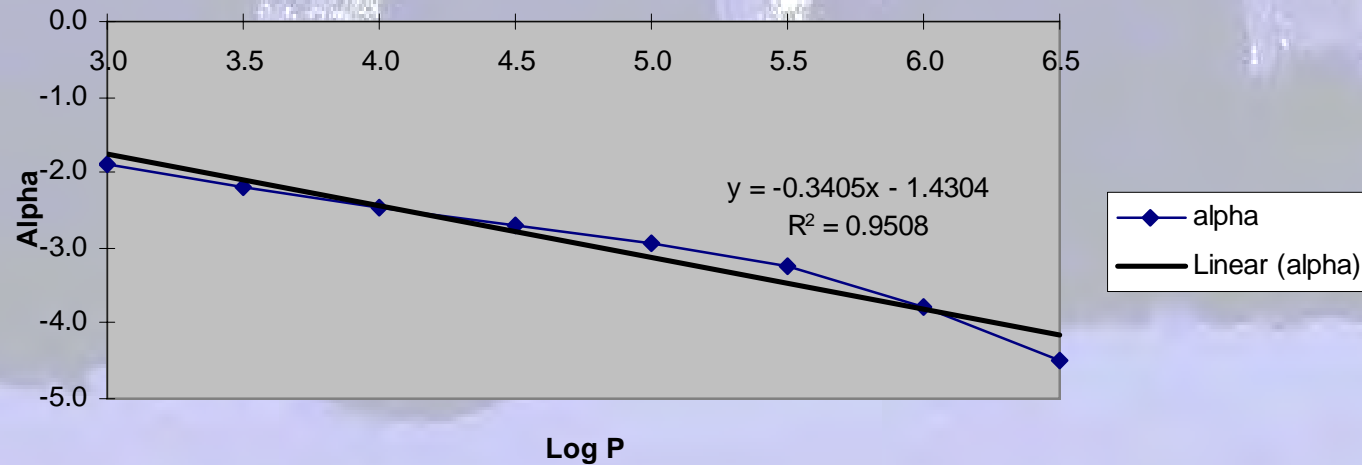
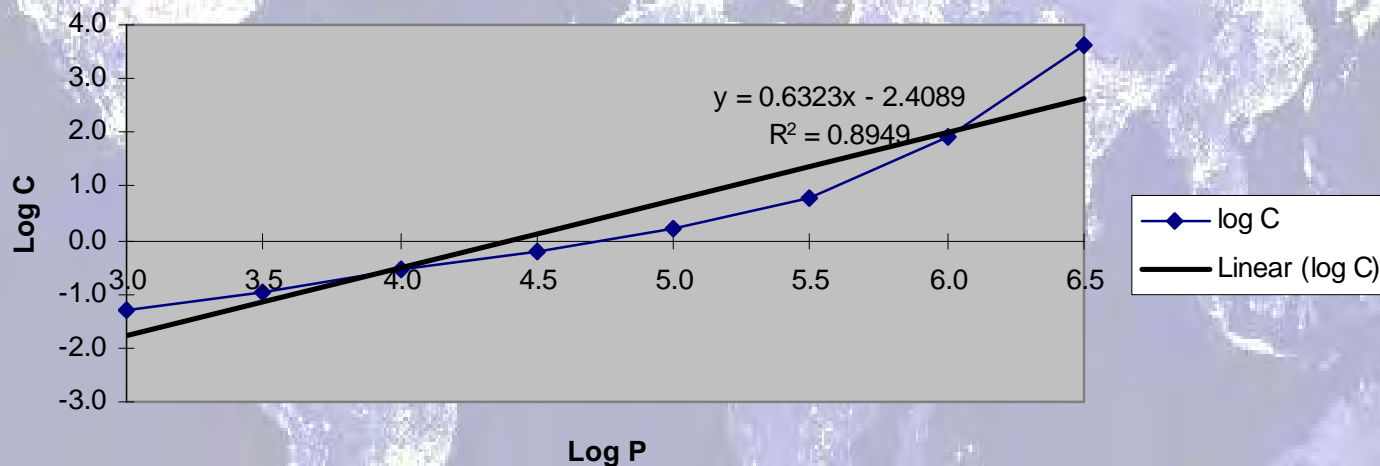
# Light, Urban Model Effects (LUME)



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## Parameterize C & $\alpha$ in $I = C P D^\alpha$





# Light, Urban Model Effects (LUME)

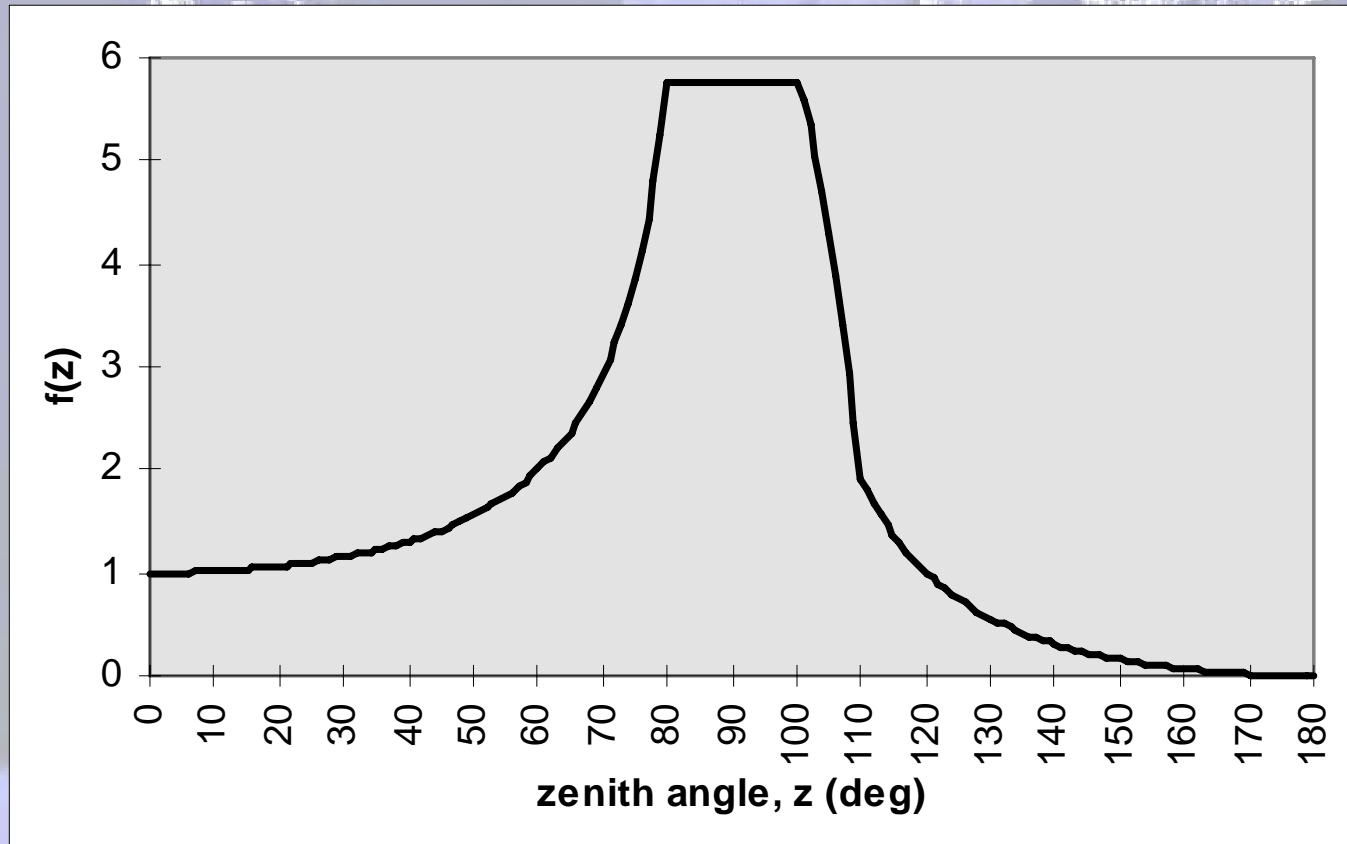


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## Correct zenith brightness for variations in zenith angle

$$f(z) = a \sec(z)$$





# Light, Urban Model Effects (LUME)

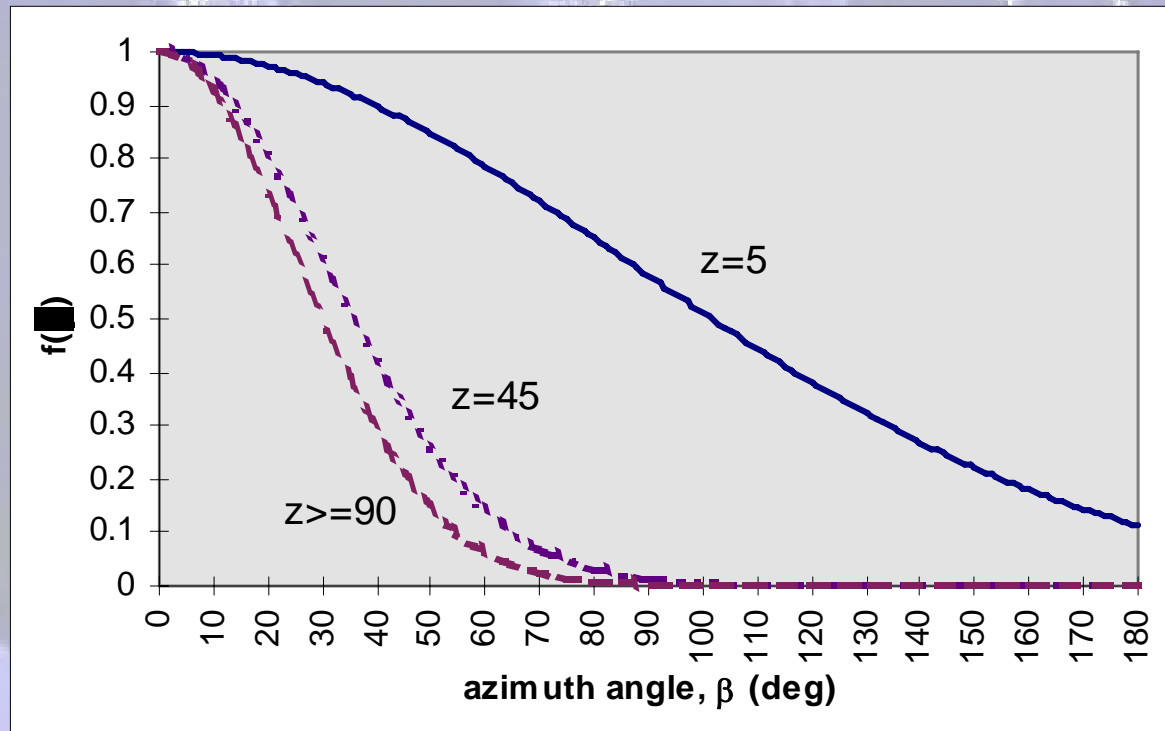


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## Azimuthal variations in urban brightness levels

$$f(\beta) = e^{\left(\frac{-\beta^2}{2F\sigma^2}\right)}$$





# Light, Urban Model Effects (LUME)



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Brightness is then calculated via

$$B = CPD^{\alpha} f(z) f(\beta)$$

where  $C$  and  $\alpha$  are determined  
as  $f(P)$  via tabular lookup



# Lighting Databases

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## Two approaches

- Broadband broken down spectrally
- DSMP via brightness atlas



# Broadband broken down spectrally



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- Estimate broadband brightness
  - measure visual brightness
  - apply population vs. intensity relation
- Light sources
  - identify spectral composition
  - estimate percentage contribution
- Allocate total brightness with these percentages

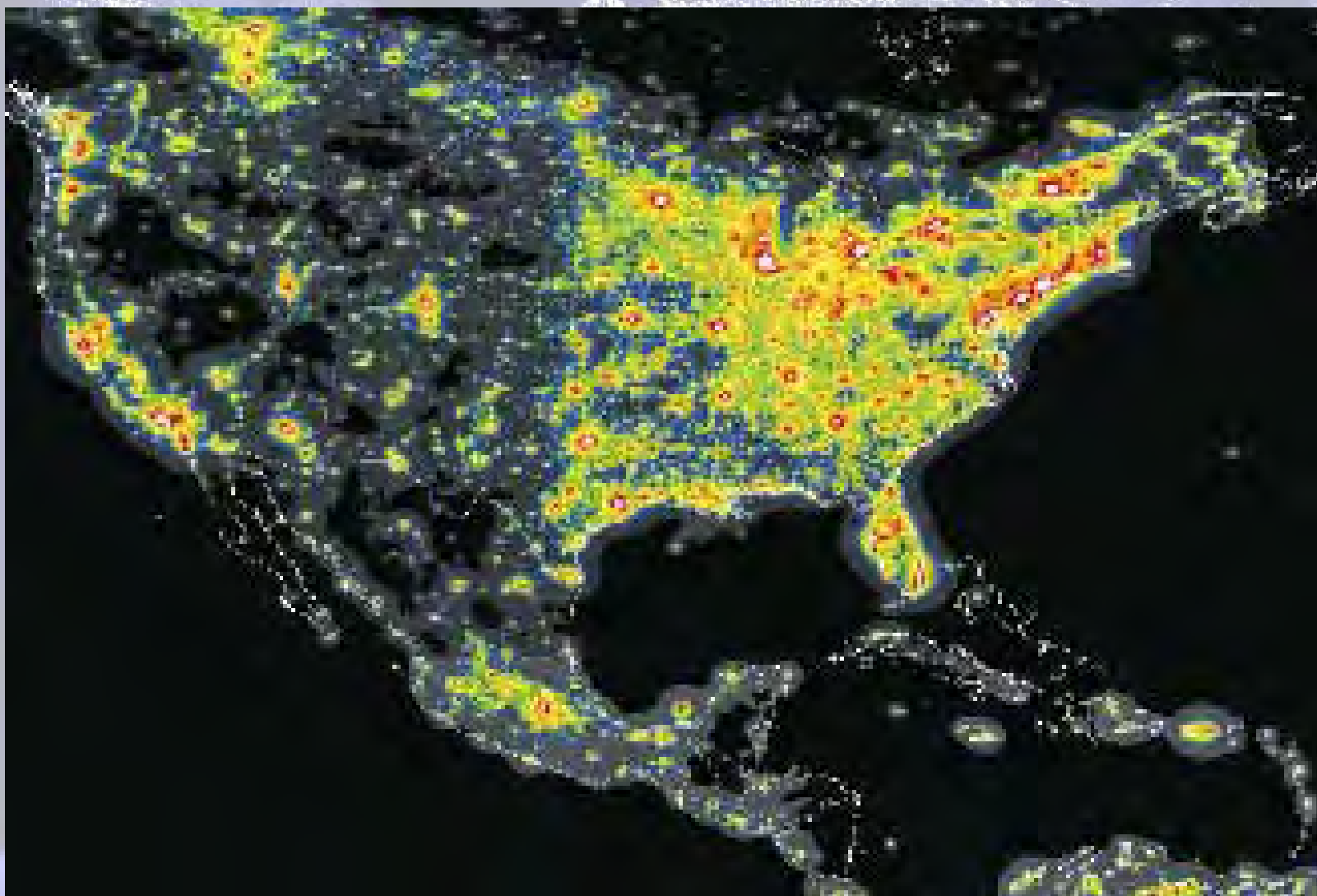


# DSMP via brightness atlas



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# Work is just beginning Requirements are being gathered

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