

Modeling Wildland Fire with DIRSIG

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May 12, 2004

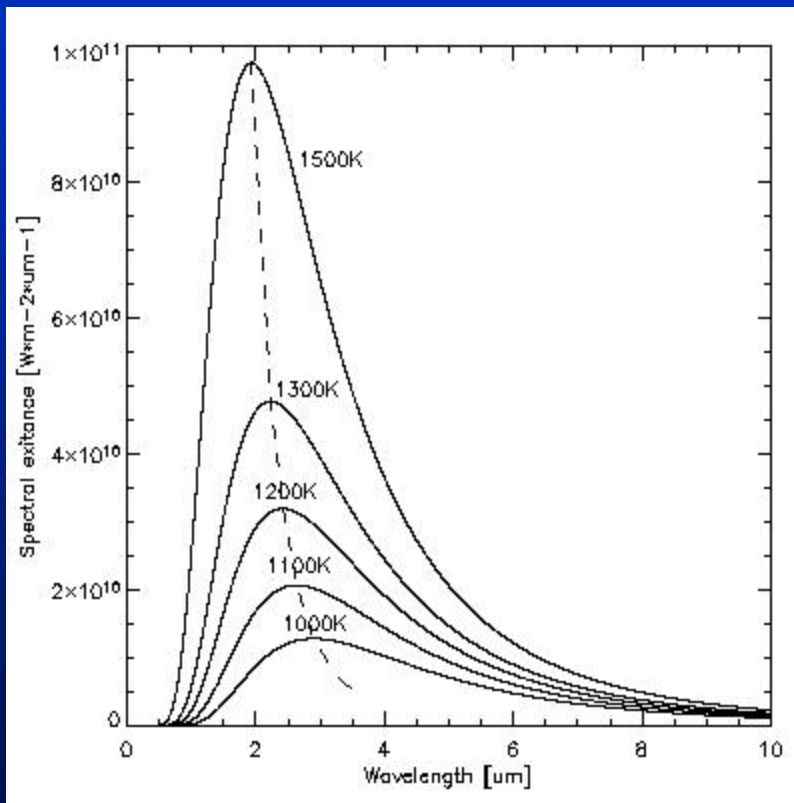
Overview

- **Why create synthetic fire images?**
- **Blackbody radiation and visualized color in DIRSIG**
- **Flame pattern**
- **Model fire as emitting spheres**
- **Simulated hyperspectral image of wildland fire**

Why create synthetic fire images?

- Utilize radiation emissions from fire to create a 3D rendering of a scene to generate a synthetic multispectral or hyperspectral image of wildfire, which can be used to evaluate detection algorithms and sensor platforms

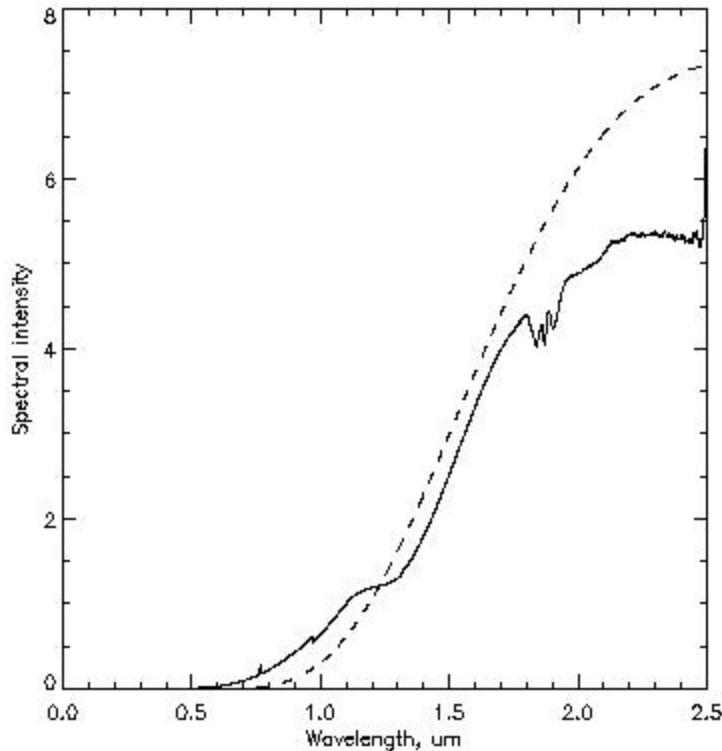
Blackbody Radiator



The Planck equation for blackbody spectral radiant exitance

$$M_{\lambda} = 2\pi hc^2 \lambda^{-5} \left(e^{\frac{hc}{\lambda kT}} - 1 \right)^{-1} [\text{wm}^{-2} \mu\text{m}^{-1}]$$

Real Visible Near-Infrared Fire Spectrum vs. Blackbody



- Blackbody radiation from Planck Equ. at 1100K
- Fire spectrum was measured using ASD, which is Analytical Spectral Devices, hand held field spectral radiometer

Digital Imaging and Remote Sensing Image Generation (DIRSIG)

- Utilize DIRSIG model to predict radiance
 - *First principles based*
 - *multi-spectral 0.28 to 20 micrometer*
 - *ray tracing*
 - *arbitrary number of spectral bands*
- The DIRSIG model is utilized to produce high spatial and spectral resolution synthetic remote sensing images

Example DIRSIG scene

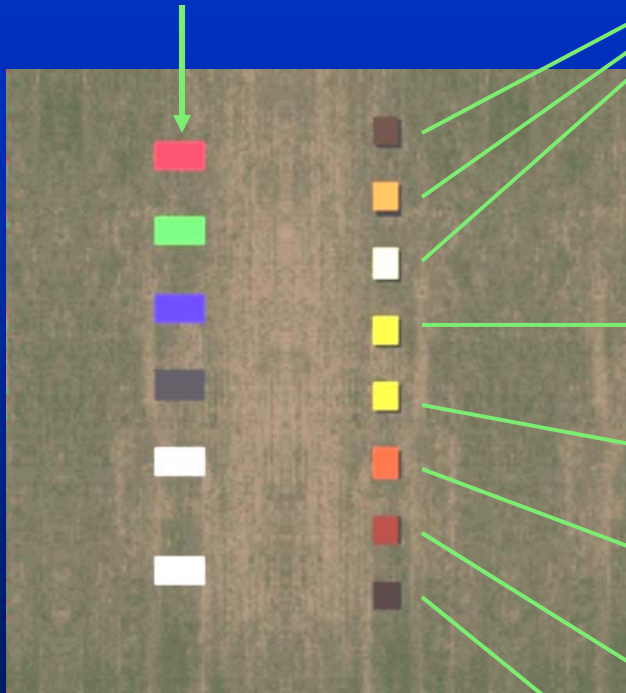


Elements needed to run DIRSIG

- **Planck emission (simulate fire spectrum)**
- **Geometric database for objects**
- **Atmospheric data (to calculate downwelling and upwelling radiance)**
- **Visualize remote scene in color**

Blackbody Radiant Temperatures Visualized in DIRSIG

Color panels



Sodium emission with various intensities

Blackbody radiation

T=1500K

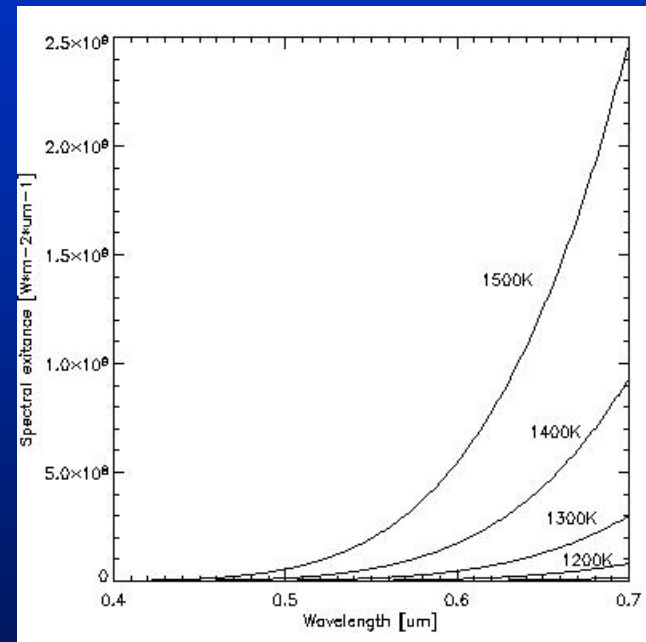
T=1400K

T=1300K

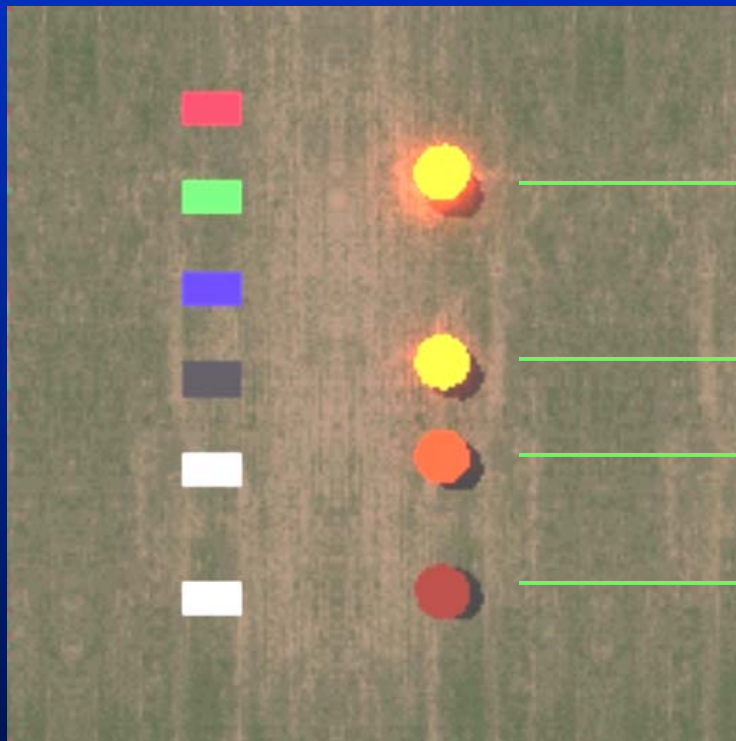
T=1200K

T=1100K

flat panels on the ground



Blackbody Radiant Temperatures Visualized in DIRSIG



Blackbody radiation

T=1500K

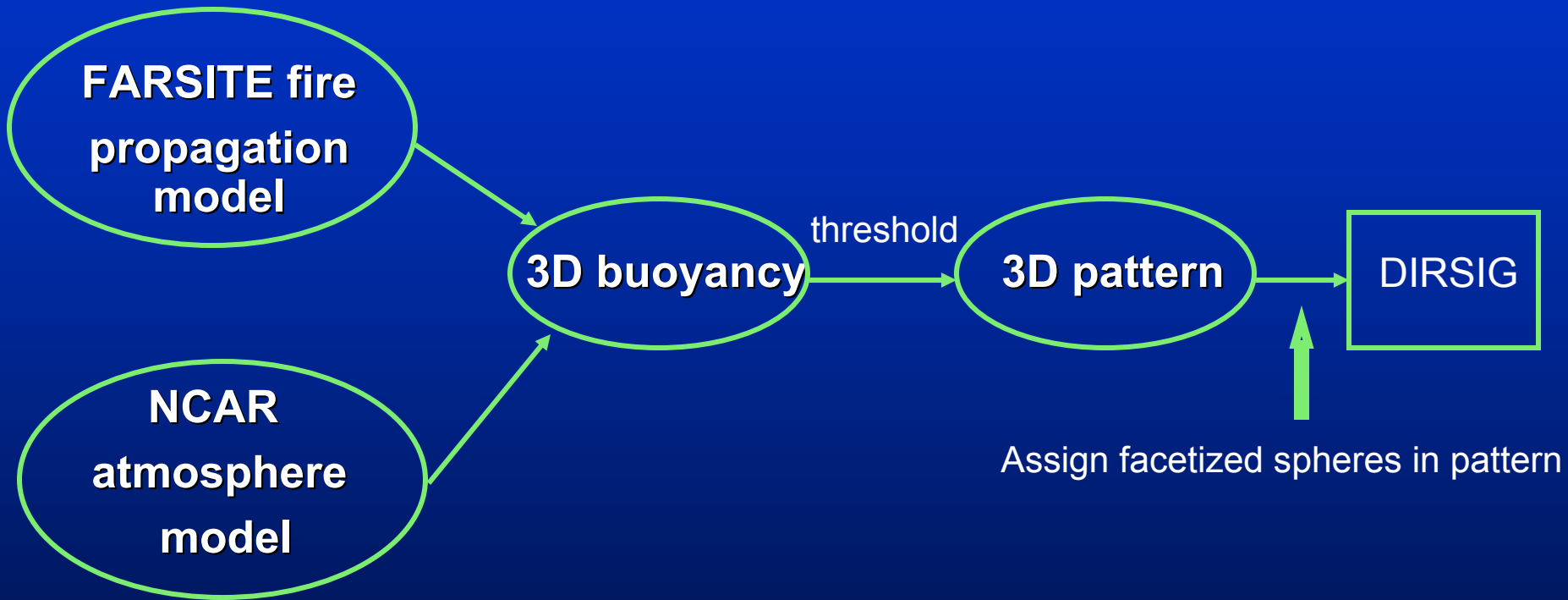
T=1400K

T=1300K

T=1200K

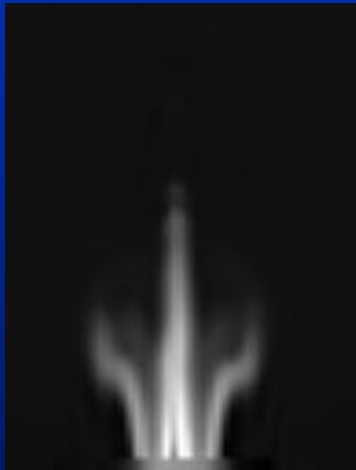
Spheres sitting on the ground

Flame Pattern

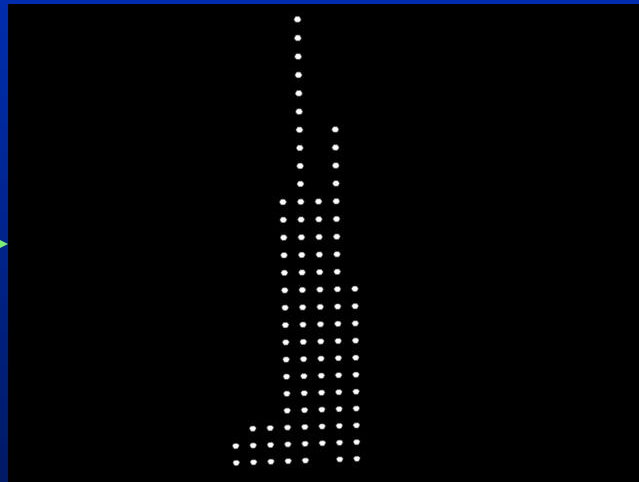


Create object of fire using spheres

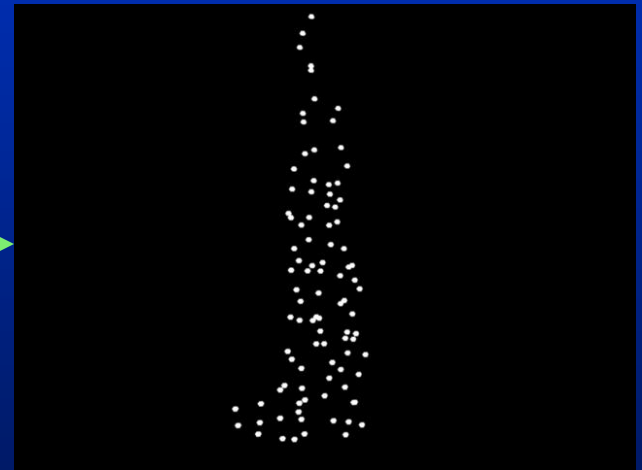
3D buoyancy field



Threshold the buoyancy

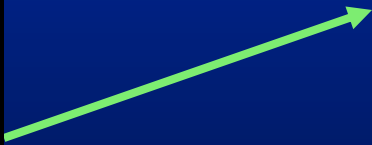
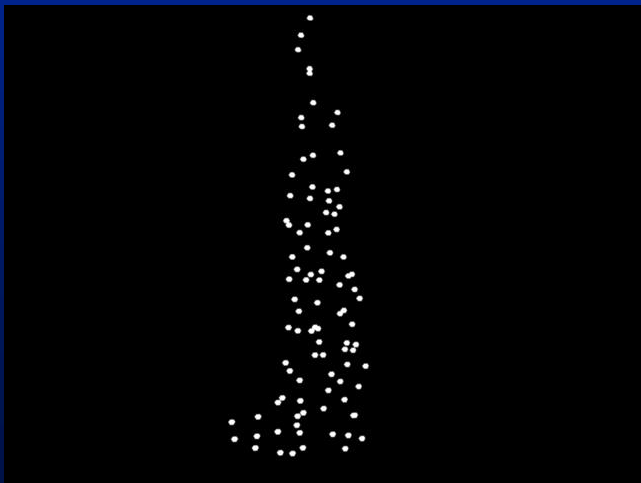
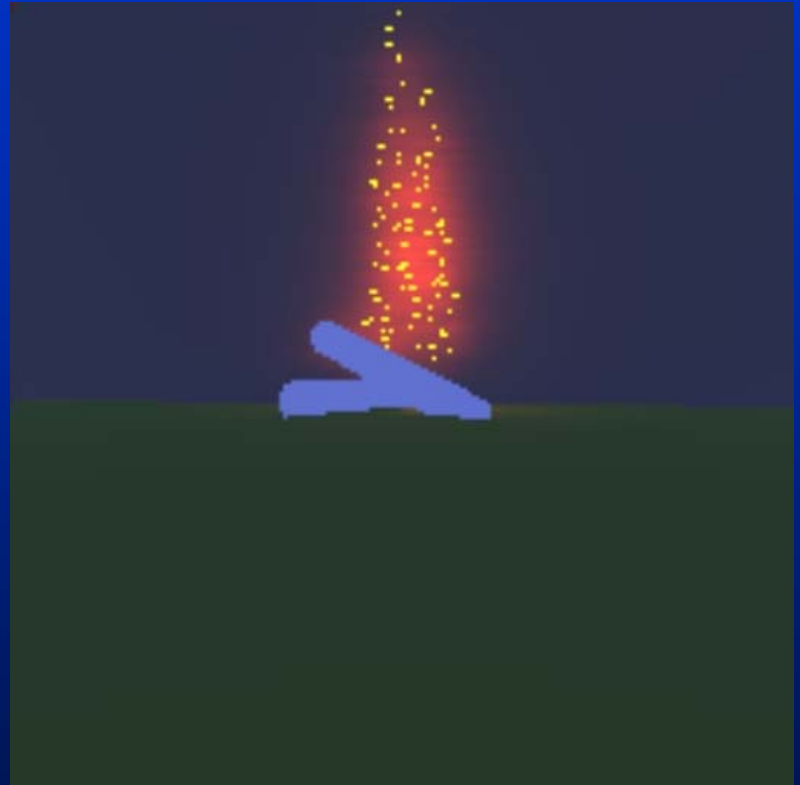
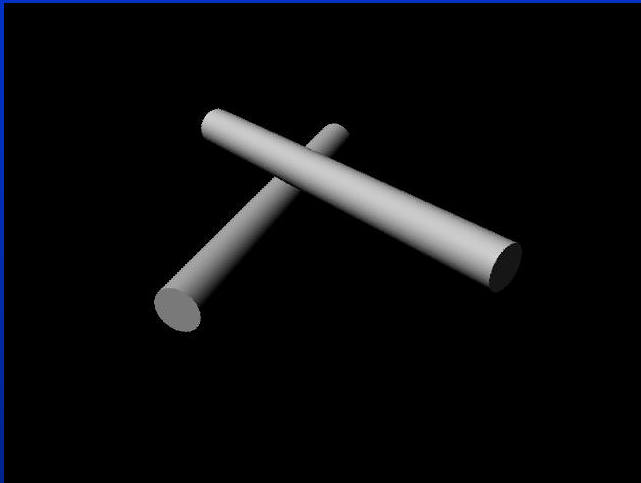


Shift spheres with random small distance



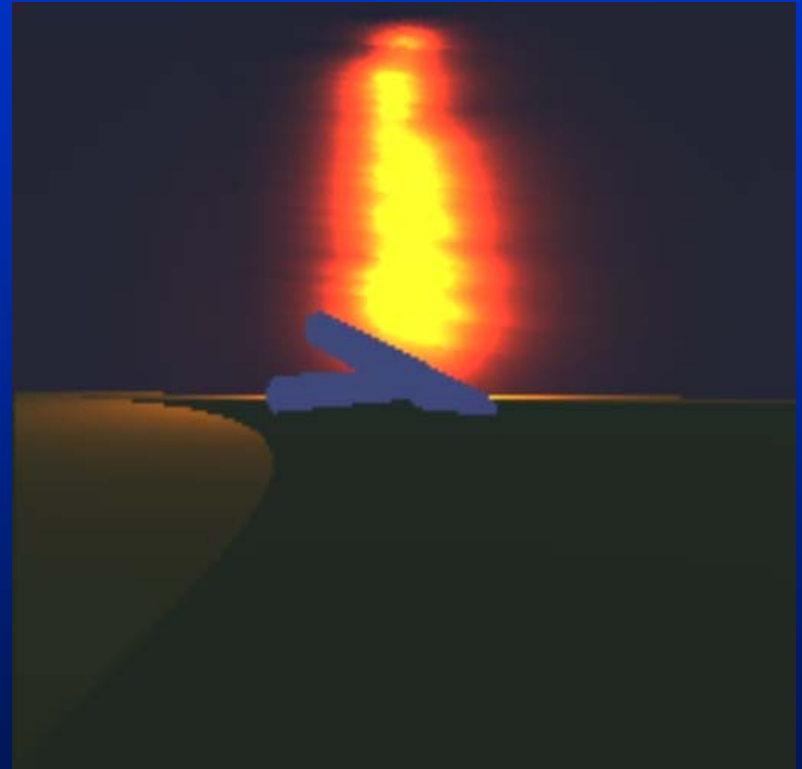
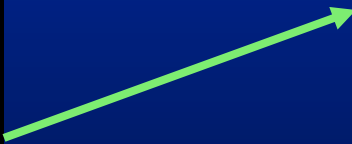
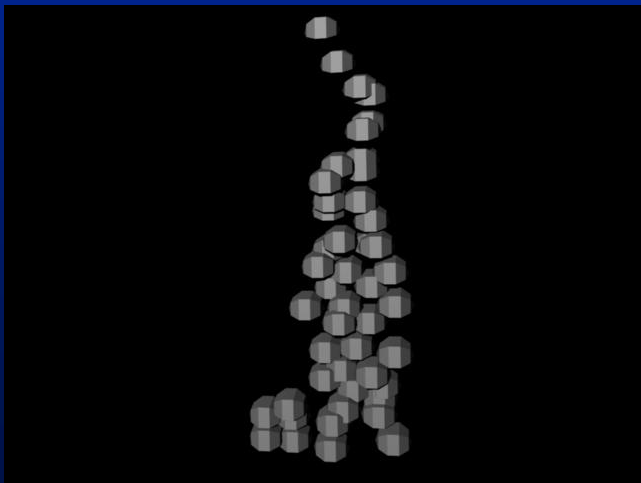
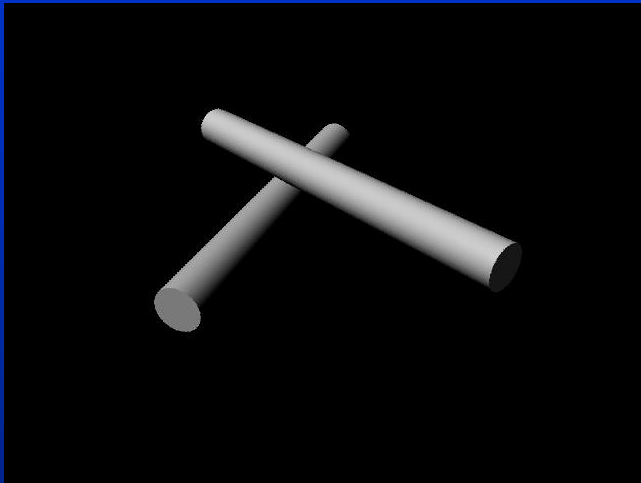
Grayscale display of pattern from coupled atmosphere-fire model

Oblique Rendering in DIRSIG



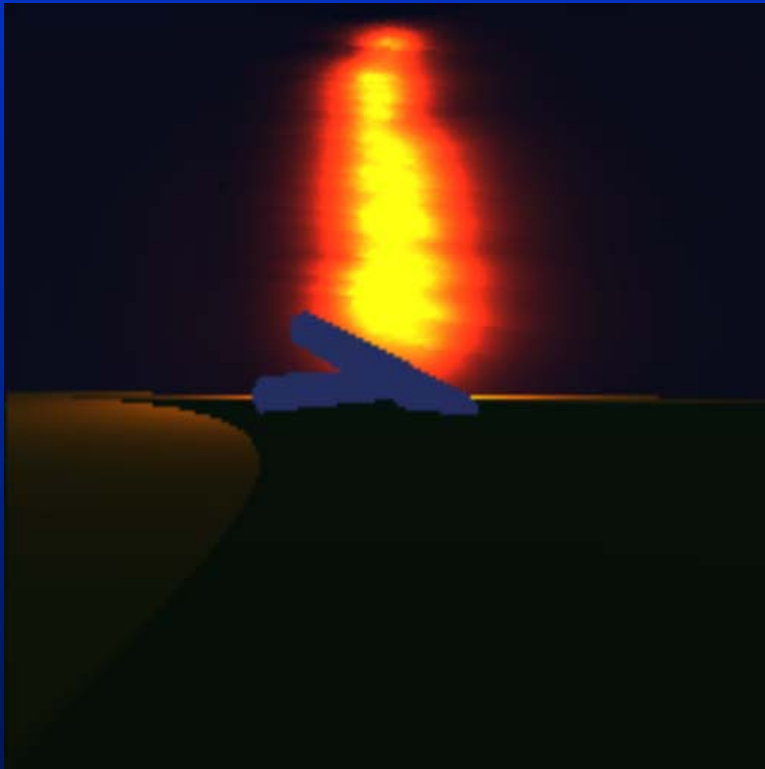
Small spheres (particles)
with panel in rear

Oblique Rendering in DIRSIG

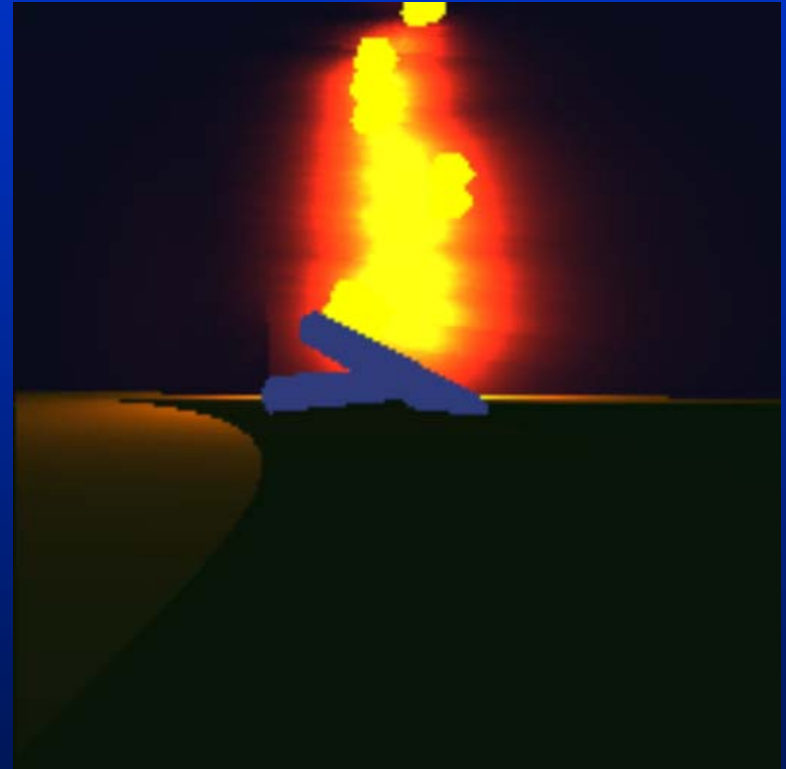


Large interacting spheres
with panel in rear

Flame patterns with different buoyancy thresholds



higher threshold = fewer spheres



lower threshold = more spheres



Original image



Segmentation



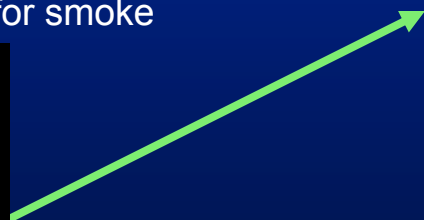
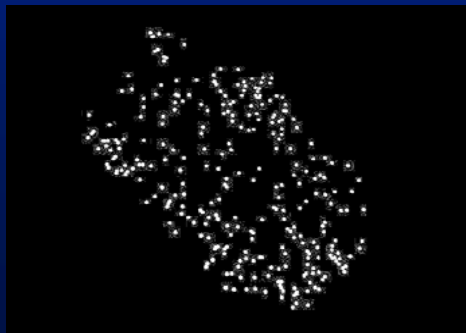
Material map



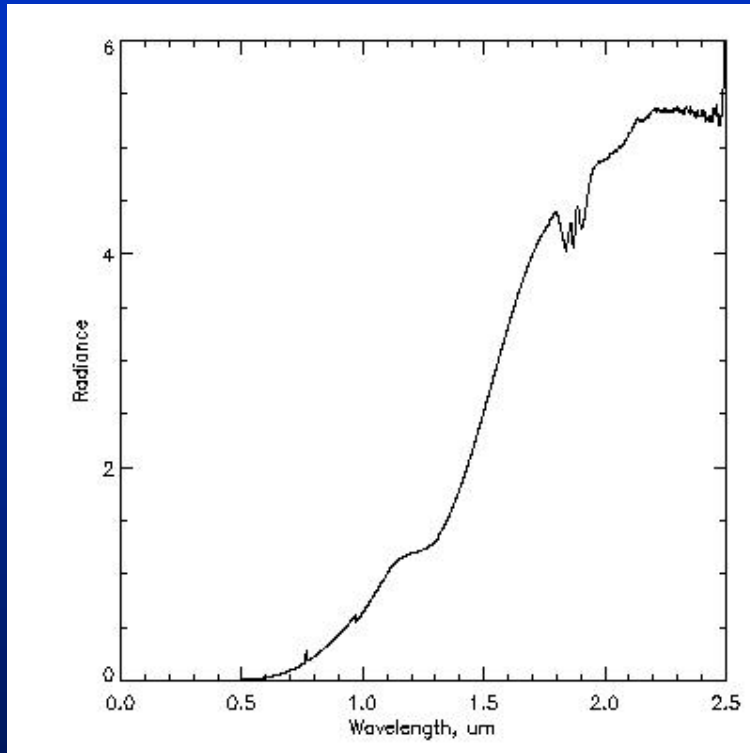
Grass Texture map



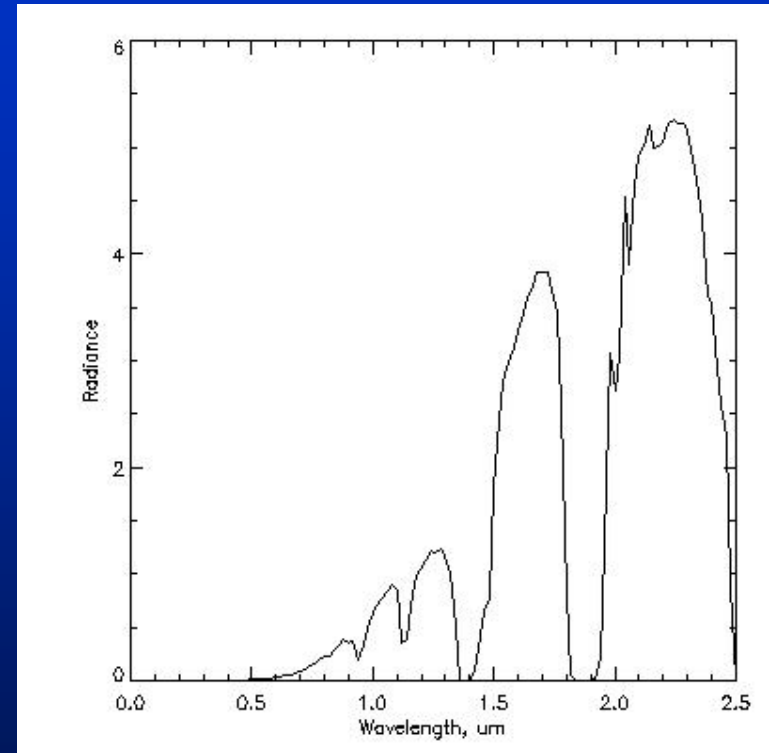
Buoyancy threshold range for smoke



Synthetic image



Input ground-level fire spectrum from ASD



Simulated fire spectrum from a remote platform with atmospheric attenuation

What next

- Real fire and smoke are semi-transparent, not solids
- Incorporate extinction and scattering properties along with blackbody radiation, 3D temperature field, and voxels to simulate different flame thickness and smoke

