Observing the Atmosphere

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Atmos 3200/Geog 3280
Mountain Weather and Climate
To become more familiar with the atmosphere ...

- Before class, make visual observations of the atmosphere. Discuss in class!
- Take pictures and share!

- Monitor visibility
- Study the sky
- Identify the clouds
- Investigate what falls from the sky
- Watch daily weather maps

Thursday, January 17, 19
Today’s Goals

- Background: observing the atmosphere
- Vision
- Radiative processes
- Color
- Visibility and haze
- Scattering & Refraction
- Photography
- Meteorological acoustics
Vision

For something to be visible, light must come from it. The image that you see, however, is produced and/or altered by interactions of radiation and matter ...
Interactions of radiation with matter:

- **Emission** (internal energy to radiative energy)
- **Absorption** (radiative to internal energy)
- **Scattering** (radiative to internal to radiative energy; modifying the radiative field in frequency, direction of propagation, polarization)

  Elastic or Conservative (only directional change, frequency remains the same)
Radiative Processes

• **Emission** - the process by which electromagnetic radiation is emitted from an object.

• **Absorption** - the process by which electromagnetic radiation is absorbed by an object.

• **Scattering** - the process by which small particles in the atmosphere deflect radiation from its path into different directions.

• **Reflection** - the process whereby a surface turns back a portion of the radiation that strikes it.

• **Refraction** - the bending of light as it passes from one medium to another.

• **Diffraction** - the bending of light around objects, such as cloud and fog droplets, producing fringes of light and dark or colored bands.
## Atmospheric phenomena & related processes

<table>
<thead>
<tr>
<th>Emission</th>
<th>Reflection</th>
<th>Refraction</th>
<th>Diffraction</th>
<th>Scattering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>Moon</td>
<td>Rainbow</td>
<td>Corona</td>
<td>Sky color</td>
</tr>
<tr>
<td>Lightning</td>
<td>Undersun</td>
<td>Parhelia</td>
<td>Green flash</td>
<td>Cloud cover</td>
</tr>
<tr>
<td>Fire</td>
<td>Cloud</td>
<td>Halo</td>
<td>Iridescence</td>
<td>Crepuscular ray</td>
</tr>
<tr>
<td>Meteorite</td>
<td>Rain, snow, hail</td>
<td>Mirage</td>
<td>Aureole</td>
<td>Pollution</td>
</tr>
<tr>
<td>St Elmo’s fire</td>
<td>Contrail</td>
<td>Snow crystal</td>
<td>Fogbow</td>
<td>Haze</td>
</tr>
<tr>
<td>Aurora</td>
<td>Water surface</td>
<td>Icicle</td>
<td>Brockenspectre</td>
<td>Whiteout</td>
</tr>
<tr>
<td></td>
<td>Ice surface</td>
<td></td>
<td></td>
<td>Blue haze</td>
</tr>
<tr>
<td></td>
<td>Tornado</td>
<td></td>
<td></td>
<td>Snow shadow</td>
</tr>
<tr>
<td></td>
<td>Dust devil</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Schaeffer & Day, 1981)
Reflected light from oceans and land surfaces

The moon is seen in reflected sunlight

NASA photo
Wavelength of visible light is 0.4 to 0.71 micrometers.

Most of the objects we see are illuminated by solar radiation. Reflection from objects gives us colors.

But: sky color is produced by scattering.

Schaeffer and Day, 1981
Visibility and Haze

• **Visibility:** The *greatest distance* in a given direction at which it is just possible to see and identify with the unaided eye 1) in the daytime, a prominent dark object against the sky at the horizon, and 2) at night, a known, and preferable unfocused, moderately intense light source.

• **Visibility** is an important indicator of how settled the atmosphere is. Poor visibility - local airmass is relatively settled and stable. Good visibility - unsettled, unstable. A lower visibility is usually caused by small pollution particles that intercept and scatter light from objects being viewed.
Haze

- **Blue haze**: Grand Canyon, Western US. Does not appreciably obscure visibility, but provides beautiful *opalescent blue* quality to distant objects. Comes from 0.1 to 0.3 micron particles thought to be produced *naturally by vegetation* (11,000 terpenes!). Other natural hazes of this type are less blue (GSMNP), with a whitish hue caused by swelling of aerosols or combination of salt haze of oceans.

- **Gray haze**: obscures distant objects by reducing contrast with sky; is also natural. Caused by relatively large particles (5-30 microns) of soil, salt and other mineral material. There is a peak in Spring with pollen grains and spores. These settle, but can be re-entrained by convection.

- **Brown to smoky blue haze**: produced by humans, industrial (*anthropogenic*). Cities, industrial plants, auto traffic, dwellings. This can be controlled by reducing noxious gases NOx, SO4, CO, HC, airborne particles. Some hygroscopic - affinity for water or other liquids. Photochemical smog, sunlight, brownish cast due to NO2. Crepuscular rays, flashlight at night.
Scattering

Haeckel, 1999
Scattering

- the process by which small particles in the atmosphere deflect radiation from its path into different directions.

- elastic and inelastic scattering (energy transfer)

- the most effective scatterers for visible light are spherical particles of diameter 0.6 micrometers. They scatter light effectively in all directions, but with maximum scattering occurring on a line between the observer and the light source.
Rayleigh Scattering and Mie Scattering

Rayleigh scattering: small particles: diameter $\ll$ wavelength; but highly wavelength dependent!

$\text{Particle diameter} \quad I \approx \frac{1}{\lambda^4}$

Direction of passing light beam

Rayleigh scattering: small particles: diameter $\ll$ wavelength; but highly wavelength dependent!

Mie scattering: particles of diameter $\approx$ wavelength; NOT very wavelength dependent!

Haeckel, 1999
Rayleigh Scattering

- Scattering by air molecules, i.e. diameter $<< \lambda$
- Strongly wavelength dependent $I \approx 1/\lambda^4$

Visible light

- Blue sky during the day
- Red solar disc at sunset
Mid-day: relatively short path through atmosphere

Rayleigh Scattering & the blue sky

Scattered light is more likely to be of shorter wavelength, i.e. blue skies
Rayleigh Scattering & the red sunrise / sunsets

Morning / evening: long path through atmosphere

- Red sunsets and sunrises

- Blue light most likely to be scattered (shortest $\lambda$)
- Red light least likely to be scattered (longest $\lambda$)
Mie Scattering

- Scattering by aerosols, hydrometeors, i.e. diameter \( \approx \lambda \)
- NOT very strongly wavelength dependent

**Visible light**

- Red: longer wavelengths
- Orange
- Yellow
- Green
- Blue: shorter wavelengths

- “Grey” overcast day / grey dark or white bright clouds

- Strong directional dependency
  - “forward scattering”

All wavelength are scattered, no colors preferred.
Mie Scattering
Refraction in raindrops

Bending of light as it passes from one medium to another (or across large density gradients).

source: Wikimedia Commons / Brocken Inaglory
Refraction

Bending of light as it passes from one medium to another (or across large density gradients).

How are mirages produced?

- **Superior mirage**, "looming"
- **Inferior mirage**

Density changes in the atmosphere of air are associated with the temperature structure!
Inferior mirage

Haeckel, 1999

Salar de Uyuni (Bolivien) © Bernhard Mühr
Superior mirage

Mc Murdo Station, Antarctica

Haeckel, 1999
Looming

Farallon Islands

source: Wikimedia Commons / Brocken Inaglory
Denali, “Looming” and superior mirage.  

(c) Phillip Wilson

Thursday, January 17, 19
The Green Flash

Haeckel, 1999
Observing tools: Photography

- Still photography, polarizing & haze filters
- Time lapse photography
- Video photography, some video cameras have time-lapse feature
- Photogrammetry - a remote sensing technology in which geometric properties about objects are determined from photographic images. Compare stereoscopy.
azimuth-elevation grid on a photograph

convert angles to meters given the distance to the object
Meteorology Department webcam
http://www.inscc.utah.edu/~krueger/covecam/

http://home.chpc.utah.edu/~u0553130/Camera_Display/wbbw.html
Iris Feigenwinter, Martina Grudzielanek
Meteorological acoustics

• Science that treats of meteorological sounds and of meteorological effects on sound. Concerned with any sound with a distinctly meteorological origin.

• Examples: humming of phone lines, roaring of mountains, rumbling of thunder, creaking of snow, howling of wind, brontides, whispering of trees, murmuring of the forest, rustle of leaves, patter of rain, rattle of sleet, clatter of hail, sizzle of St. Elmo’s fire, detonation of meteorites, etc.

• Velocity of sound in still air: \( \sim 330 \text{ m/s} \). Compare to 300,000,000 m/s velocity of light.

• Sound reflection and refraction

• Locating by sound
References