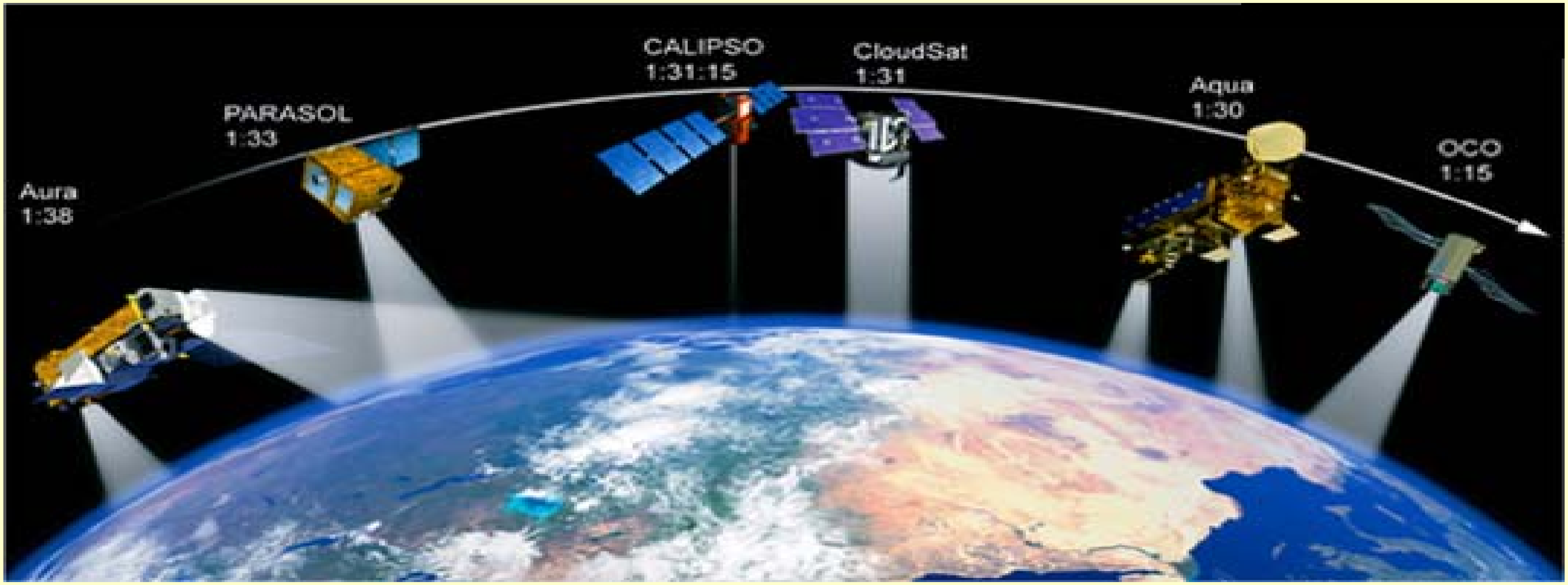
Lecture 16.

Review for mid-term exam II/ Problem solution examples

"A-Train" satellite constellation and more..



<u>Current satellite technologies</u>**:**

- **Polar orbiting and geostationary**
- **Various viewing geometry (downlooking, limb, etc.)**
- **Passive and active**
- **Various spectral coverage and resolution (broad-band, narrow-band, hyperspectral, etc)**
- **Various spatial and temporal sampling**
- **Various applications**

QUIZ

FALSE/TRUE

1) Bidirectional Reflectance Distribution Function (BRDF) describes the reflectance from an object as a function of the viewing geometry at the time of measurement and its absorption and scattering properties (T)

2) Atmospheric window is used in an airborne sensor to reduce the transmittance of the atmosphere by filtering aerosols, therefore measuring radiance reducing the influence by the atmosphere (F)

3) Wien’s displacement law establishes the relationship between the true temperature of a blackbody and emitted radiation (F)

4) Swath is a field of view of a satellite sensor (F)

Propagation of the electromagnetic radiation in the atmosphere-underlying surface system is governed by:

- **atmospheric composition (gases, aerosol particles, cloud particles and precipitation)**
- **state of the atmosphere (temperature, pressure, air density)**
- **reflectivity and emissivity of surfaces**

Remote sensing using emission in the thermal (IR and microwave) regions.

IR

(Lecture 11)

$$I_\nu^\uparrow(\tau;\mu) = \varepsilon_\nu B_\nu(\tau^*)\exp\left(-\frac{\tau^*-\tau}{\mu}\right) + \frac{1}{\mu}\int_\tau^{\tau^*}\exp\left(-\frac{\tau'-\tau}{\mu}\right) B_\nu(\tau')\,d\tau'$$

MICROWAVE

$$T_{b,\nu} = \varepsilon_\nu^p T_{sur}\exp(-\tau^*/\mu) + \int_0^{\tau^*} T_{atm}(\tau')\exp(-\tau'/\mu)\,d\tau'/\mu + R_\nu^p\exp(-\tau^*/\mu)\int_0^{\tau^*} T_{atm}(\tau')\exp(-(\tau^*-\tau')/\mu)\,d\tau'/\mu$$

Radar equation

$$\frac{P_r}{P_t} = \pi^2 G^2 \frac{h\theta_{HP}\varphi_{HP}}{128 R^2} |K|^2 \int N(D) D^6 dD$$

$$P_r = C \frac{|K|^2}{R^2} Z$$

Lidar equations

MIE lidar:

$$P_r(R) = \frac{C}{R^2}\frac{h}{2}\frac{k_b}{4\pi}\exp(-2\int_o^R k_e(r')dr')$$

RAMAN lidar:

$$P_r(R,\lambda_L,\lambda_R) = \frac{C}{R^2}\frac{h}{2}\frac{k_b(R,\lambda_L,\lambda_R)}{4\pi}\exp(-\int_o^R [k_e(r',\lambda_L)+k_e(r',\lambda_R)]dr')$$

Gases:

Absorption (emission):

- **depends on molecular structure (dipole!)**
- **wavelength-selective**

Scattering:

- **a point dipole approach – Rayleigh scattering**
- **~ wavelength $^{-4}$ => important in UV-vis**
  negligible in IR-microwave

Scattering and absorption by aerosol (or cloud) particles depend on

size,

shape,

and refractive index (i.e., composition)

Scattering domains:

Rayleigh scattering regime: $2\pi r/\lambda$ <<1, and the refractive index m is arbitrary (applies to scattering by molecules and small aerosol particles)

Rayleigh-Gans scattering: **(m –1) <<1** (not useful for atmospheric application)

Mie-Debye scattering: $2\pi r/\lambda$ and m are both arbitrary but for spheres only (applies to scattering by aerosol and cloud particles)

Geometrical optics: $2\pi r/\lambda$ is very large and m is real (applies to scattering by large cloud droplets).

The size parameter $x = 2\pi r/\lambda$ is a key factor determining how a particle interacts with EM radiation

Efficiencies (or efficiency factors) for extinction, scattering and absorption are defined as

$$Q_e = \frac{\sigma_e}{\pi r^2} \qquad Q_s = \frac{\sigma_s}{\pi r^2} \qquad Q_a = \frac{\sigma_a}{\pi r^2}$$

$$Q_a = Q_e - Q_s$$

From Mie theory:

$$Q_e = \frac{2}{x^2} \sum_{n=1}^{\infty} (2n+1) \operatorname{Re}[a_n + b_n]$$

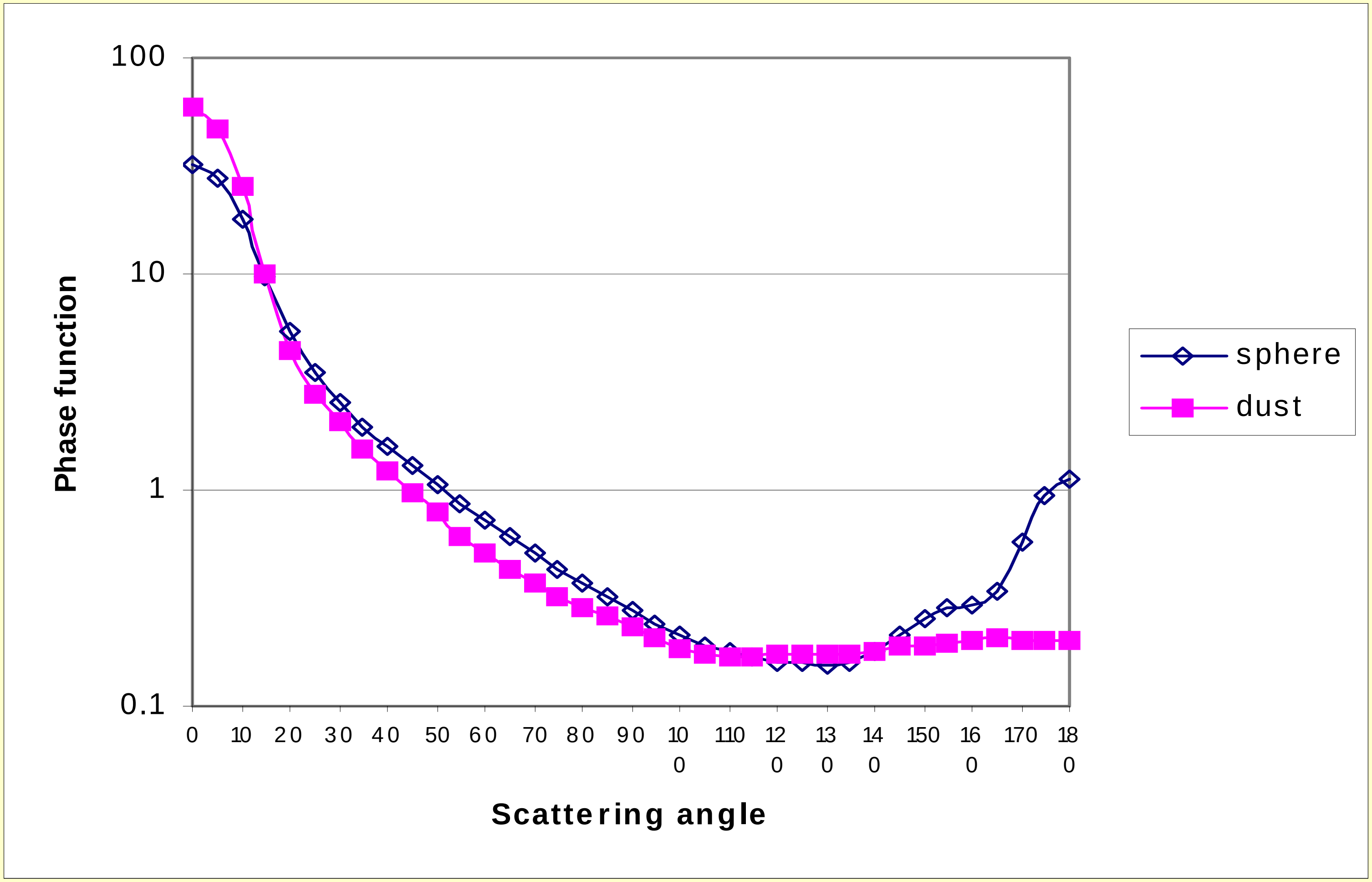
$$Q_s = \frac{2}{x^2} \sum_{n=1}^{\infty} (2n+1) [|a_n|^2 + |b_n|^2]$$

In Rayleigh scattering regime:

$$Q_a \approx -4x \operatorname{Im}\left(\frac{m^2-1}{m^2+2}\right)$$

$$Q_s \approx \frac{8}{3}x^4\left|\frac{m^2-1}{m^2+2}\right|^2 \longrightarrow Q_b \approx 4x^4\left|\frac{m^2-1}{m^2+2}\right|^2$$

Scattering function of spherica vs. nonspherical particles



Exam question examples:

Precipitation is a key component of the hydrological cycle. Briefly explain the principles and discuss advantages and disadvantages of the following remote sensing techniques:

- **passive IR sensing of precipitation**
- **passive microwave sensing of precipitation**
- **active microwave sensing of precipitation**