Remote Sensing Coastal and GIS

K. H. Rao
Retired Scientist “G” and Group Director
Ocean Sciences Group
NRSC/ ISRO, Balanagar, Hyderabad

INTRODUCTION

AVAILABILITY OF OPERATIONAL RESOURCES MONITORING SATELLITES LIKE LANDSAT, SPOT AND IRS SATELLITE SERIES, MONITORING OF COASTAL WATERS HAS BEEN UNDER TAKEN BY VARIOUS COUNTRIES ALL OVER THE WORLD.

IN INDIA WITH THE AVAILABILITY OF LANDSAT DATA DURING EIGHTIES METHODOLOGIES HAS BEEN DEVELOPED FOR MONITORING OF :

- COASTAL WATERS
- WETLANDS MAPPING,
- SHORELINE CHANGES,
- MANGROVES MAPPING ETC.

CURRENTLY NUMBERS OF SENSORS OPERATING IN VARIOUS SPECTRAL BANDS WITHIN THE VISIBLE RANGE OF ELECTROMAGNETIC RADIATION ARE USED FOR COASTAL STUDIES.

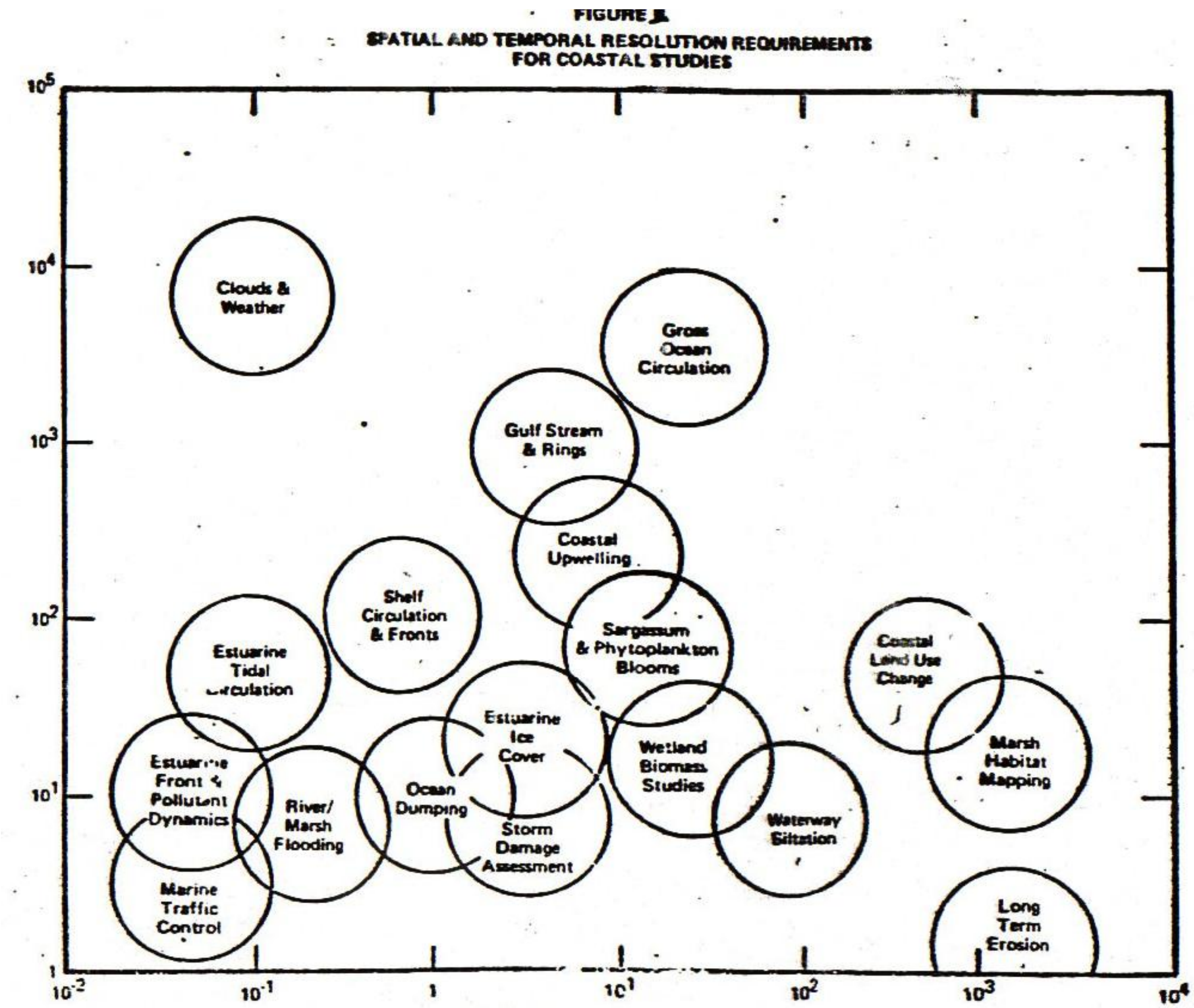
THESE SENSORS ARE HAVING DIFFERENT SPATIAL RESOLUTION WITH VARIABLE REPEATIVITY.

A WIDE VARIETY OF REMOTELY SENSED IMAGERY ARE AVAILABLE FOR COASTAL STUDIES AND HABITAT MAPPING.

ONE OF THE MOST IMPORTANT QUESTIONS TO BE CONSIDER WHEN PLANNING FOR COASTAL STUDIES IS “THE SENSOR AND DATA TO BE USED FOR MAPPING”.

REMOTE SENSING SENSORS DIVIDE THE EARTH’S SURFACE INTO A GRID OF SAMPLING UNITS CALLED PIXELS, NAMED AS SPATIAL RESOLUTION OF A PARTICULAR SENSOR.

THE SPATIAL RESOLUTION, TEMPORAL RESOLUTION AND SPECTRAL RESOLUTION ARE THE KEY SENSOR PARAMETERS REQUIRED FOR COASTAL STUDIES.

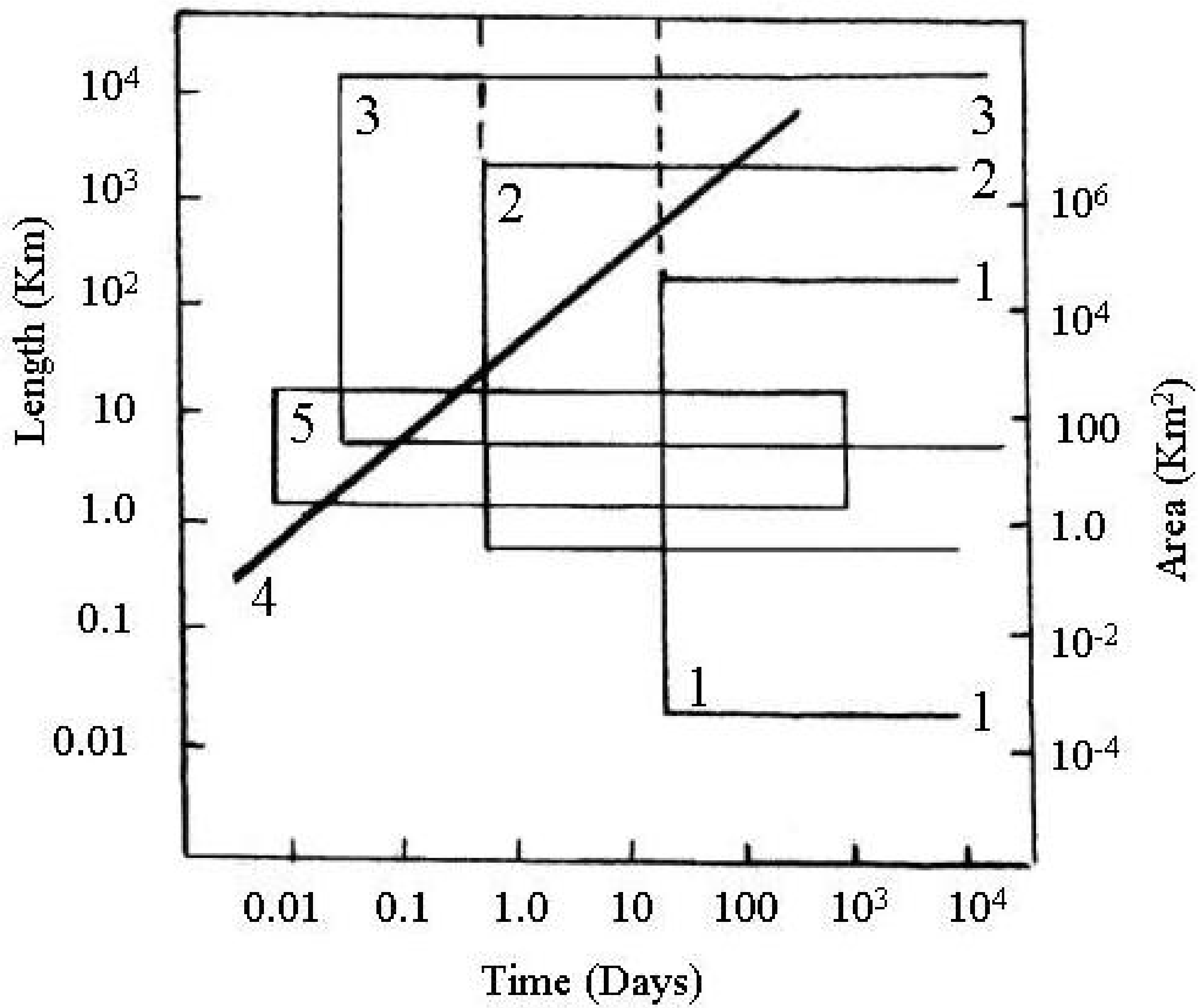


Spatial Resolution (m)

Temporal Resolution (Days)

Spatial and Temporal resolution requirements for Coastal studies.

SPATIAL AND TEMPORAL SAMPLING CHARACTERISTICS OF DIFFERENT SENSORS



SPATIAL AND TEMPORAL SAMPLING CHARACTERISITICS OF DIFFERENT MEASUREMENT STRATEGIES IN CLOUD FREE CONDITIONS. LOWER BOUND DENOTES THE SAMPLING FREQUENCIES. THE UPPER SPATIAL BOUND DENOTES THE EXTENT OF SYNOPTIC VIEWING WHICH IS POSSIBLE

1. HIGH RESOLUTION SCANNING SENSOR IN POLAR ORBIT
2. MEDIUM RESOLUTION SCANNING SENSOR IN POLAR ORBIT
3. SCANNING RADIOMETER ON GEOSTATIONARY SATELLITE
4. MEASUREMENTS FROM RESEARCH VESSEL (NO SYNOPTIC VIEW POSSIBLE, LINEAR TRANSECT ONLY)
5. BUOYS

CURRENT SPACE ASSETS

Communication Satellites

- **14 Operational**

INSAT-3A, 3C, 4A, 4B, 4CR
GSAT-6, 7, 8, 10, 12, 14, 15, 16 & 18

Earth Observation Satellites

- **Four in Geostationary orbit**

INSAT-3D, Kalpana, INSAT-3A & INSAT-3DR

- **13 in Sun-synchronous orbit**

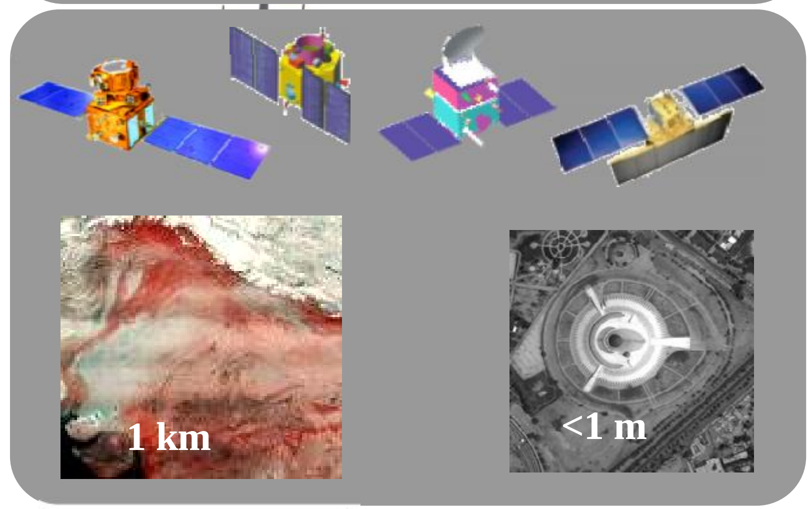
RESOURCESAT- 2/2A; CARTOSAT-1, CARTOSAT-2 series (4 Nos.) RISAT-1, RISAT-2, OCEANSAT-2, MEGHA-TROPIQUES, SARAL SCATSAT-1

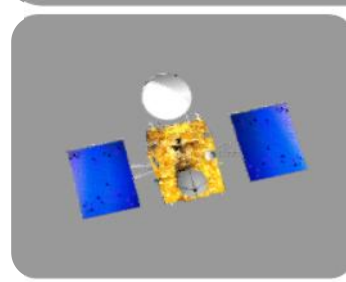
Navigation Satellites (NavIC)

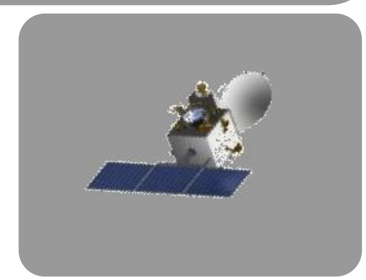
- **Full Constellation of 7 satellites realized**

Space Science

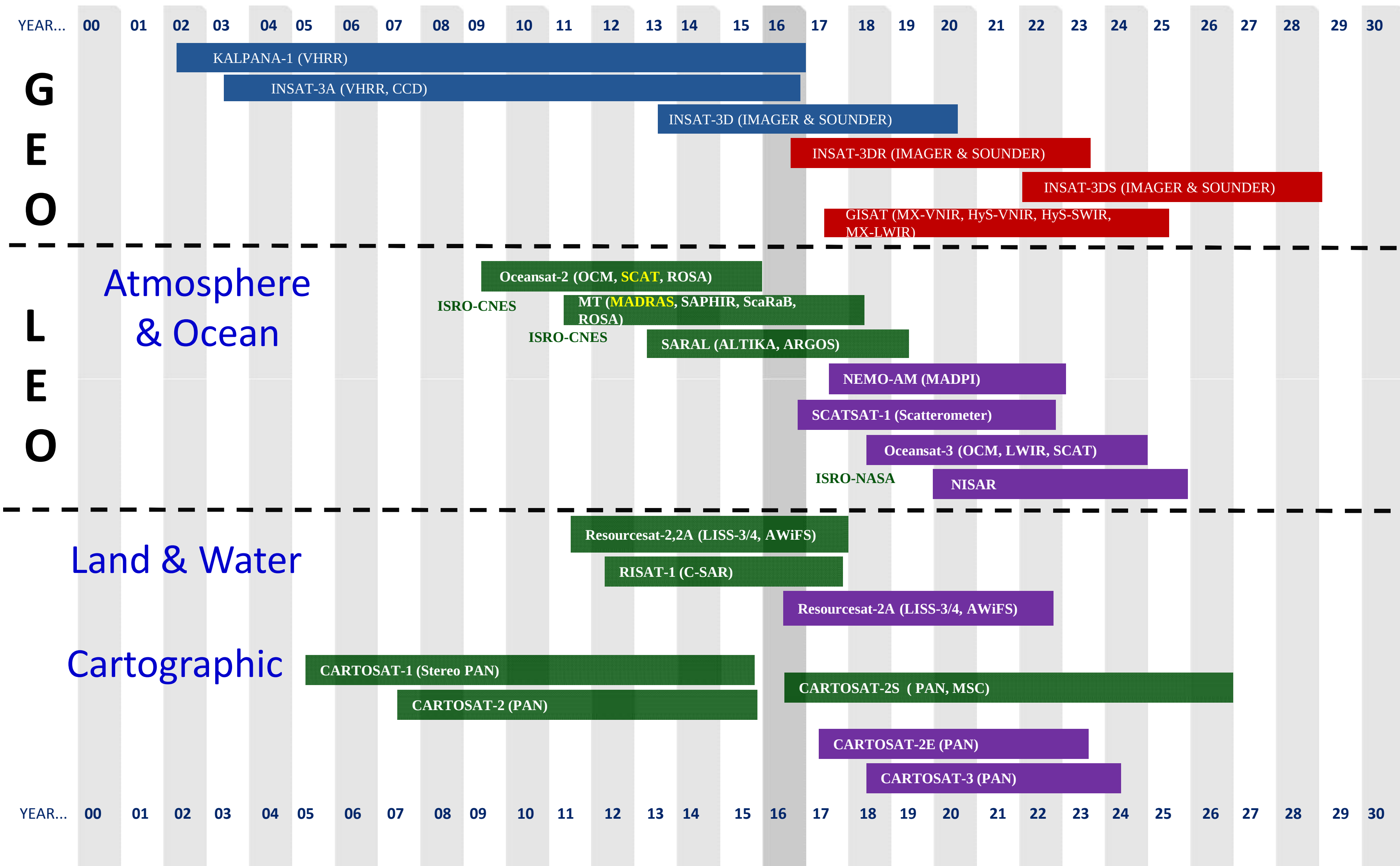
- **MOM & ASTROSAT**







ISRO Current & Future Missions for Earth Observations



EO Missions - Near Future

2017
CARTOSAT- 2D & 2E
VHR Panchromatic and Multispectral Imaging

- PAN (0.60 m, 10 km swath, 11 bit)
- Mx (2m , 10 km swath, 4 Xs, 11 bit)

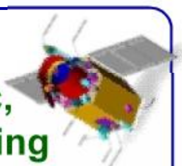
Orbit : 500 km
Local time: 0930 hrs

2018
GISAT - 1
Geosynchronous Orbit

- HR Mx VNIR : 50m; SWIR: 1.5 Km
- HYSI VNIR: 320m; WIR : 192m

Orbit : 36000 km
Every 30 min

2018
CARTOSAT-3
VHR Panchromatic, Multispectral Imaging



- PAN (0.25 m, 16 km swath, 11 bit)
- Mx (1m , 16 km swath, 11 bit)

Orbit : 450 km
Local time: 1030 hrs

2018 & 2019
Oceansat-3 & 3A
Continuity for OS-2 with Improvements

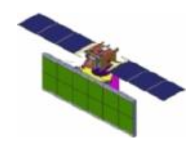
- 13 band OCM, IR-SST
- Ku-band Scatterometer ,

Orbit : 720 km
Local time: 1200 hrs

2018
RISAT-1A
Continuity for RISAT-1

- C-Band SAR

Orbit : 536 km
Local time: 0600 hrs



2019 & 2020
RESOURCESAT- 3 & 3A
Continuity for Resourcesat-2A

- ALISS-3:10m & 12m, 925 km, 5 Bands, ATCOR: 240m, 0.4-1«m, , 10 bit)

Orbit : 795 km
Local time: 1030 hrs

2019 & 2020
RS SAMPLER- 3S & 3SA
High Res. Stereo imaging

PAN Fore & AFT
APAN: 1.25m, 60Km
Mx: 2.5m, 60Km, 4 Bands

Orbit : 630 km
Local time: 1030 hrs

2020
NISAR
Joint Mission with JPL/NASA

Payloads

- L & S Band SAR

Orbit : 747 km
Local time: 0600 hrs

REMOTE SENSING

DEFINITION:

OBSERVING AN OBJECT FROM A DISTANCE WITHOUT HAVING DIRECT CONTACT WITH IT.

REMOTE SENSING SYSTEMS ARE USED TO OBSERVE THE EARTH'S SURFACE FROM DIFFERENT LEVELS OF PLATFORMS SUCH AS SATELLITES AND AIRCRAFT, AND MAKE IT POSSIBLE TO COLLECT AND ANALYZE INFORMATION ABOUT RESOURCES AND ENVIRONMENT OVER LARGE AREAS.

REMOTE SENSORS ARE GROUPED
INTO TWO CATEGORIES:

PASSIVE SENSOR

SENSE NATURAL RADIATION EITHER EMITTED
BY OR REFLECTED FROM THE EARTH'S SURFACE.

ACTIVE SENSOR

SENSORS HAVE THEIR OWN SOURCE OF
ELECTRO MAGNETIC RADIATION (EMR)
FOR ILLUMINATING THE OBJECTS.

Spatial resolution

A measure of the area or size of the smallest dimensions on the earth's surface over which an independent measurement can be made by the sensor.

A small elemental area is observed at a time by a RS sensor by means of a suitable optical telescope or other electronic means and such a field of view of the sensor is called the Instantaneous Field of View (IFOV).

Spectral resolution

The spectral resolution of the remote sensor characterises the ability of the sensor to resolve the energy received in a given spectral bandwidth to characterise different constituents of earth surface. Thus the spectral resolution is defined by the spectral bandwidth of the filter and sensitiveness of detector.

Radiometric resolution

In remote sensing the reflected radiation from different objects generate electrical signal (say voltage) as output from the detector which are converted into digital number. This is analogous to grey shades seen in a black and white photograph. The ability to distinguish the finer variations of the reflected or emitted.

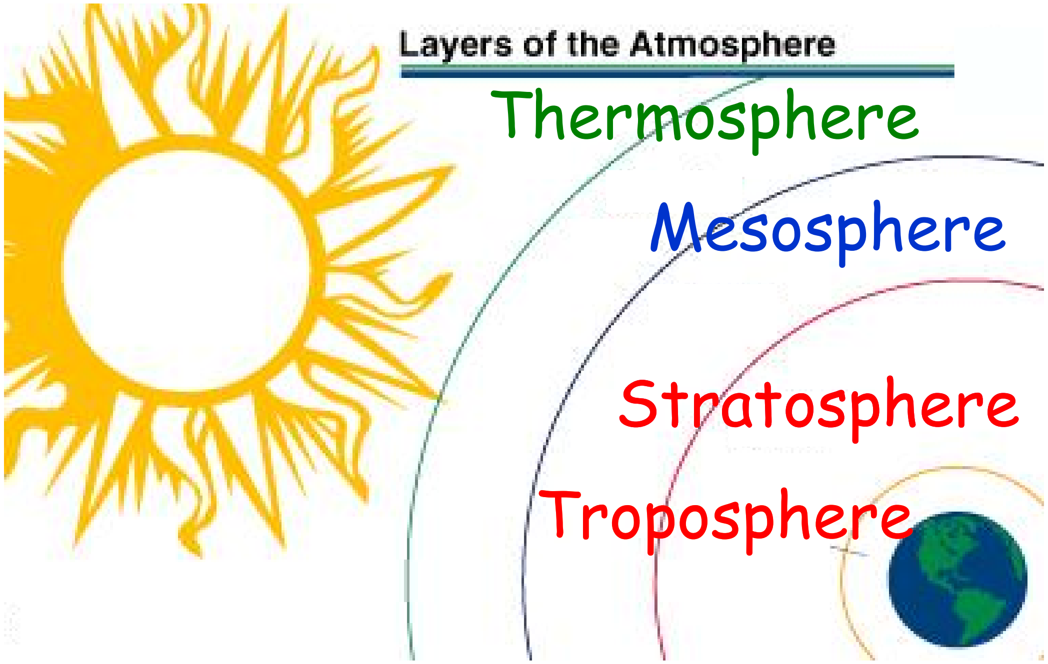
Temporal resolution

This is another aspect which is specific to space-borne remote sensors. The polar orbiting satellites can be made to orbit in what is known as "sun synchronous orbits". This means that the satellite crosses over the equator at the same local solar time in each orbit. Such an orbit offers similar sun illumination conditions for all observations taken over different geographical locations along a latitude (in the sun-lit area). By a suitable selection of the spacecraft altitude and the inclination angle of the orbit, the spacecraft can be made to cover the same area on the earth at regular intervals.

Remote sensing

Sun, Earth, and Atmosphere

The climate system on our planet is driven by the energy coming from the sun. The sunlight reaches the Earth through several atmospheric layers.



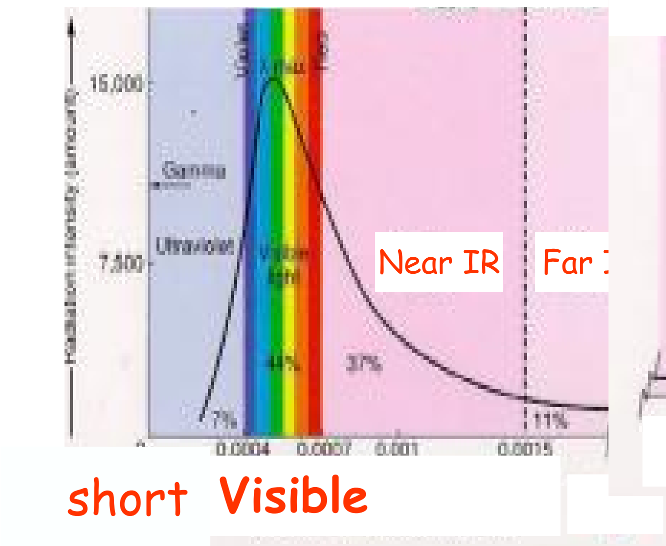
The lowest one, from the Earth surface to about 7miles height, is called troposphere.

Next layer, from 7 up to 30 miles above the surface, is called stratosphere.

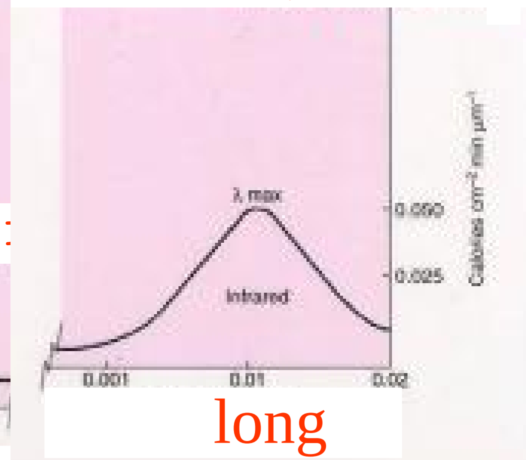
Mesosphere and thermosphere follow above up to about 50 miles height.

Earth Spectrum

Solar spectrum



Earth's spectrum



In contrast, the Earth is colder celestial body with average surface temperature of 15°C.

That is why Earth emits at longer wavelengths, called infrared (IR), visualized like this:

Electromagnetic spectrum

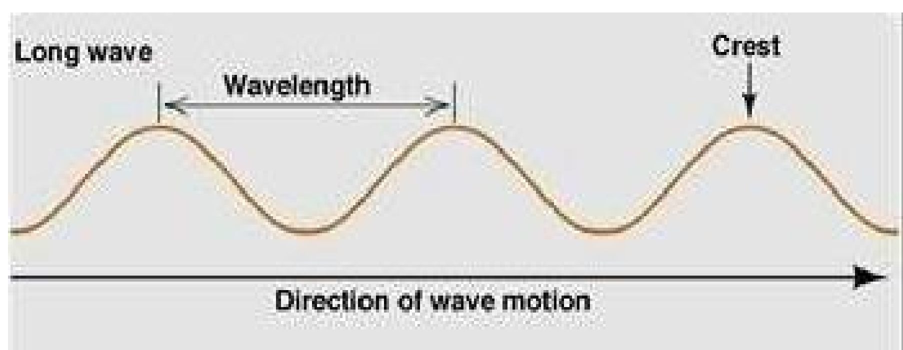
X-rays in medicine

Radio broadcasting

So, remember:

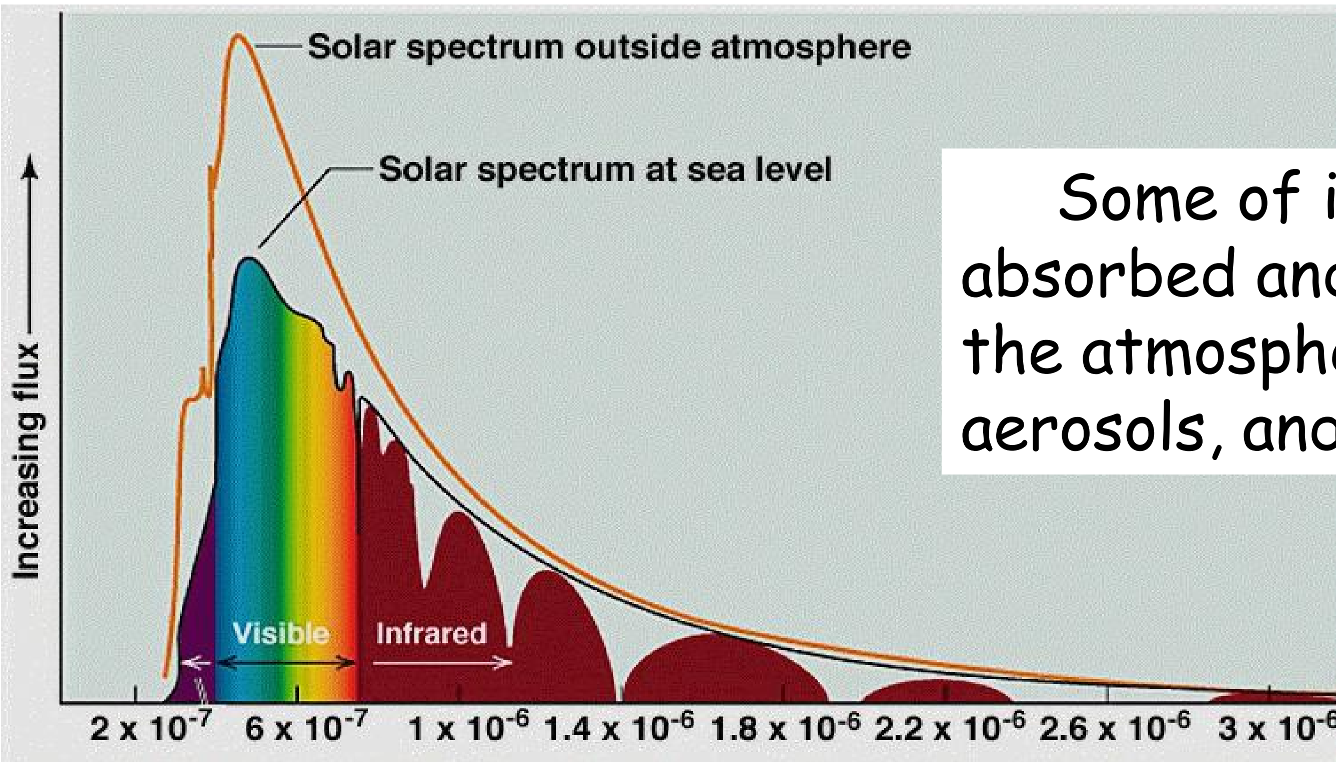
The Sun emits at short wavelengths (SW).

The Earth emits at long wavelengths (LW).



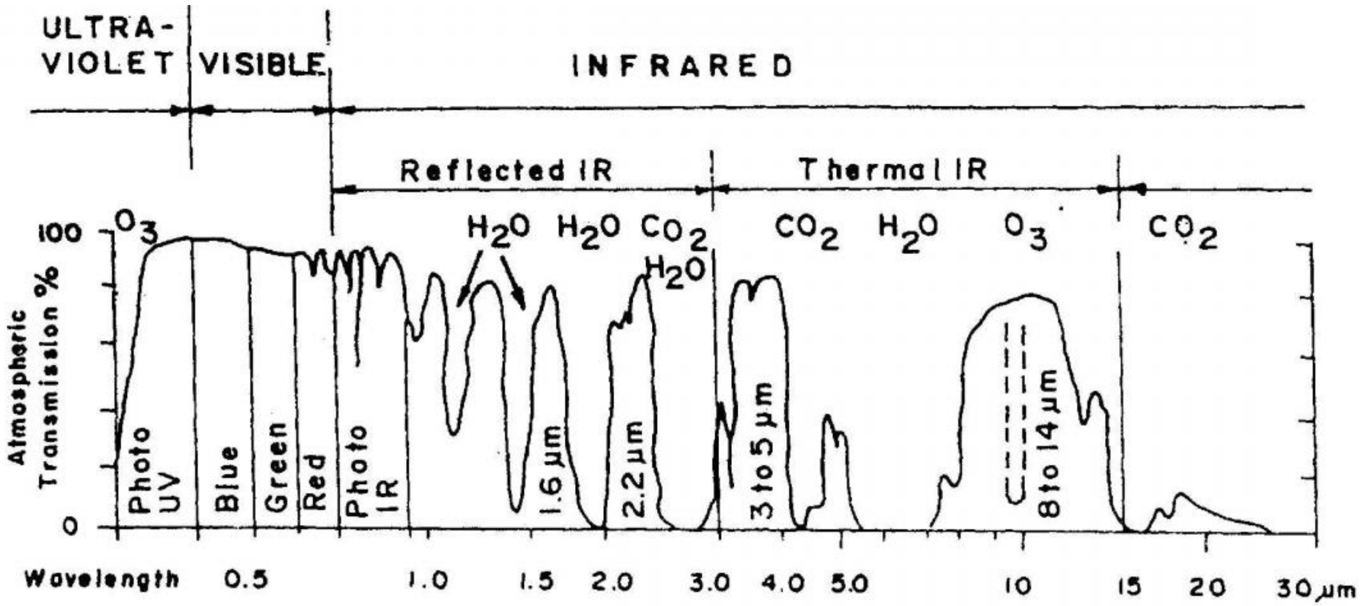
Solar energy at sea level

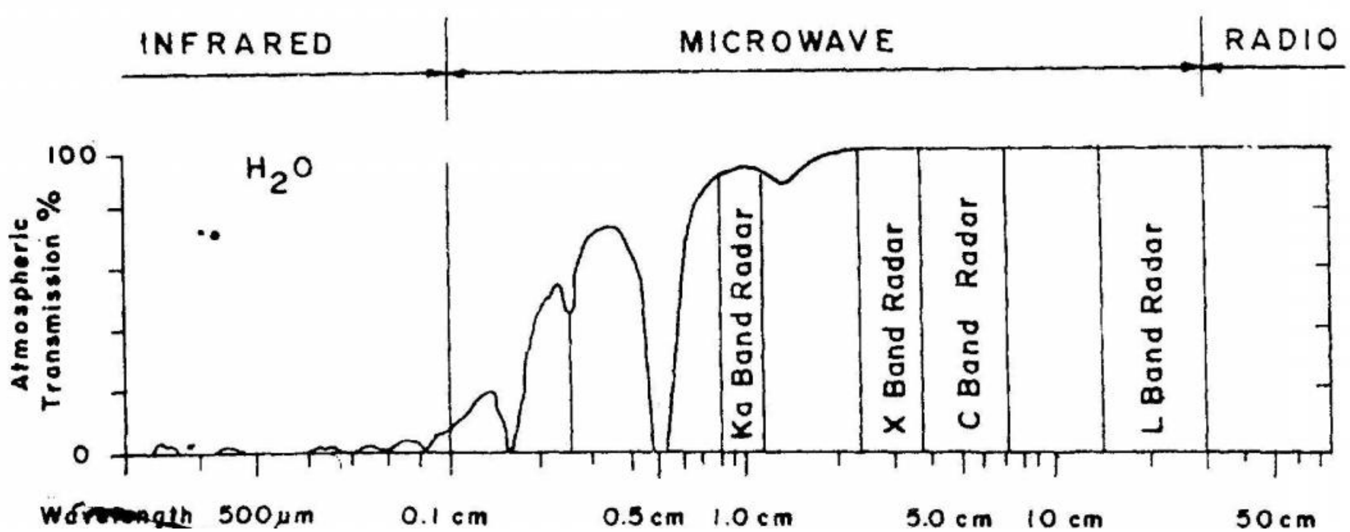
Only a part of the SW solar radiation available at the top of the atmosphere reaches the Earth.



Some of it is scattered, absorbed and reflected within the atmosphere by the gases, aerosols, and clouds.

The absorbed radiation is re-emitted by the atmospheric constituents back as a LW radiation, i.e., it is converted in heat.

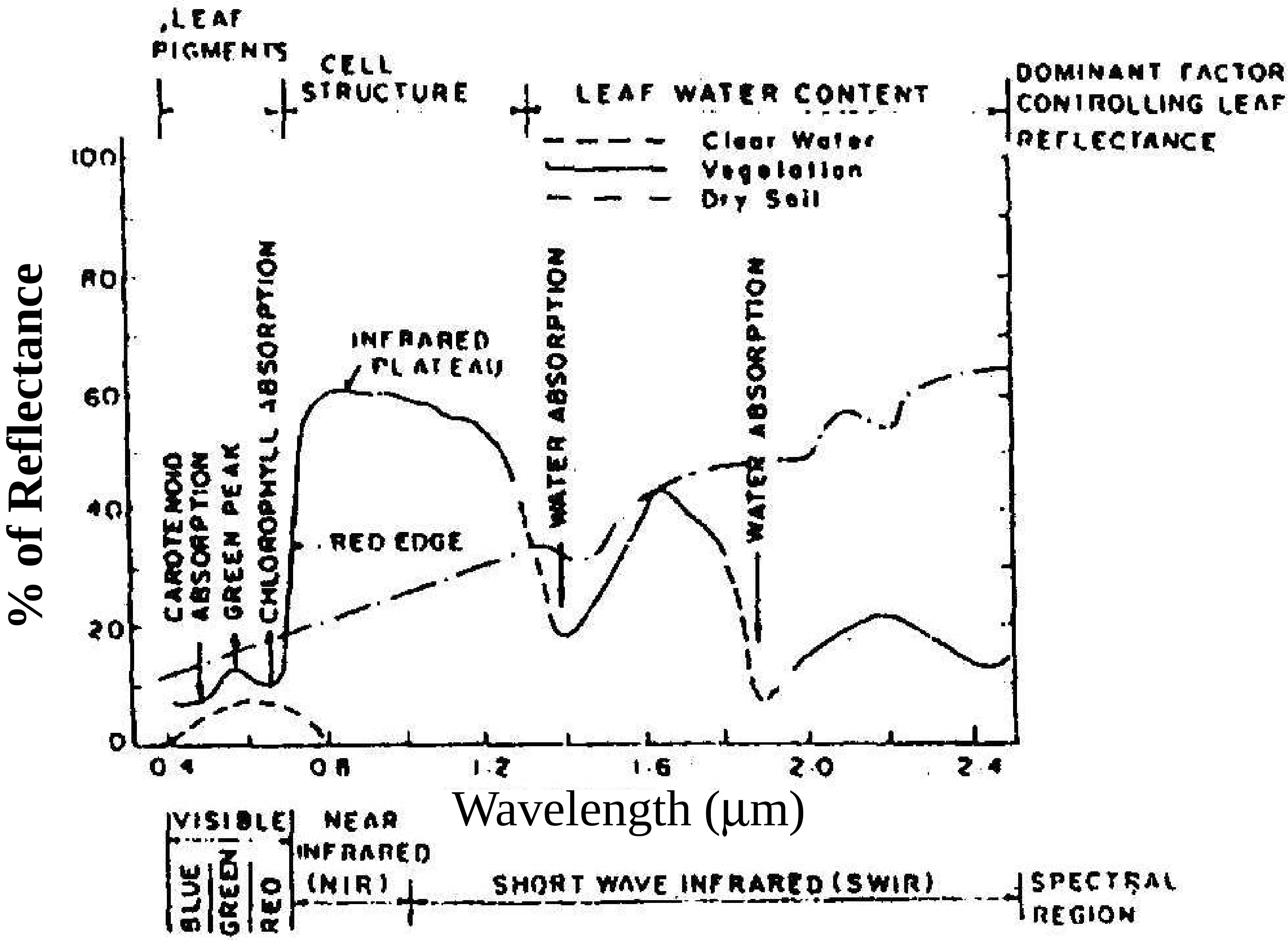




The attenuation of in coming Solar and out going earth radiation is depends upon atmospheric absorption and scattering.

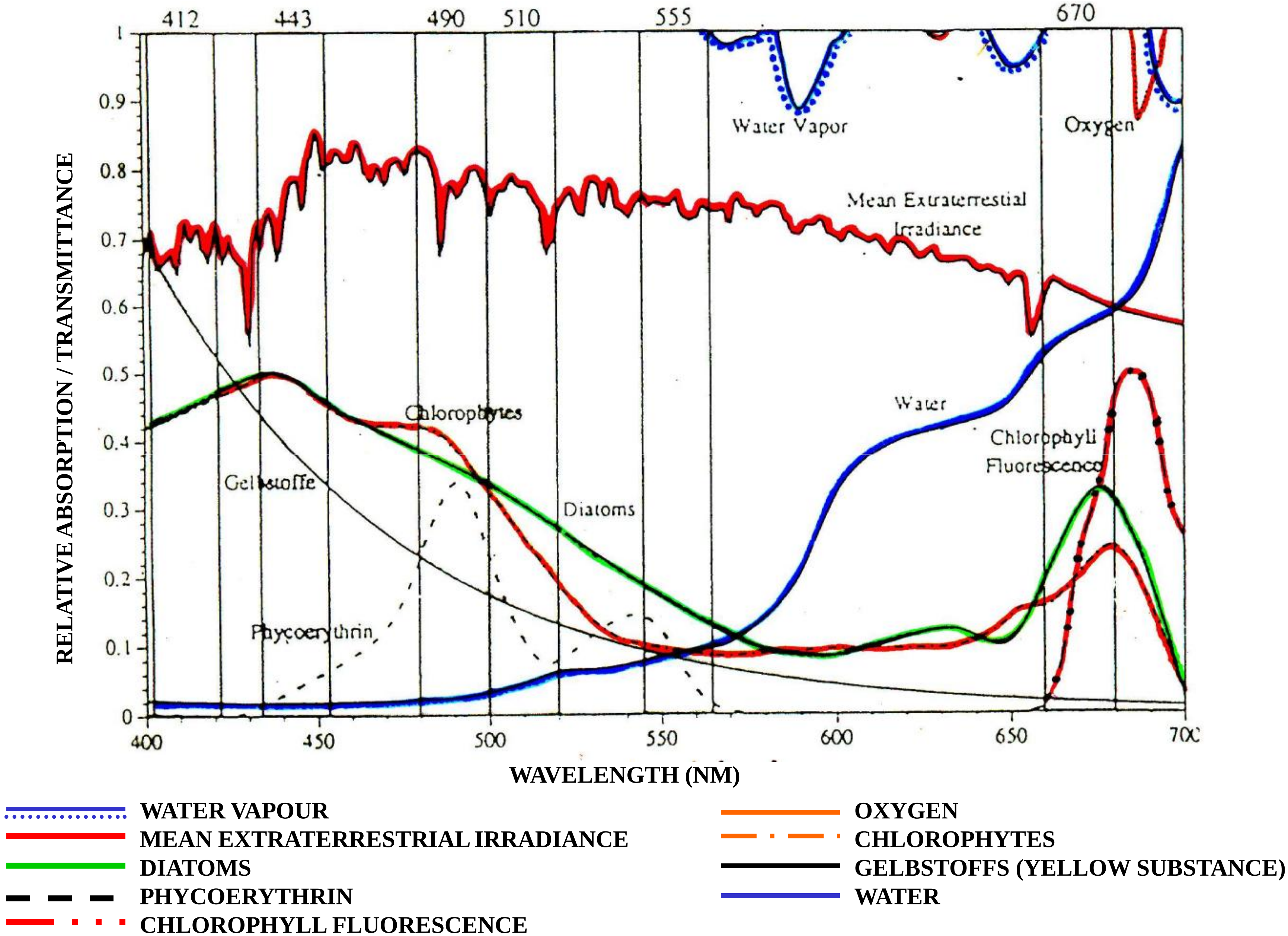
Scattering of EMR Within the atmosphere reduces the image contrast And changes are spectral signature of ground objects as seen by the sensor.

Absorption spectrum of earth's atmosphere



A typical reflectance curve of green vegetation in the visible, near infrared and mid infrared region.

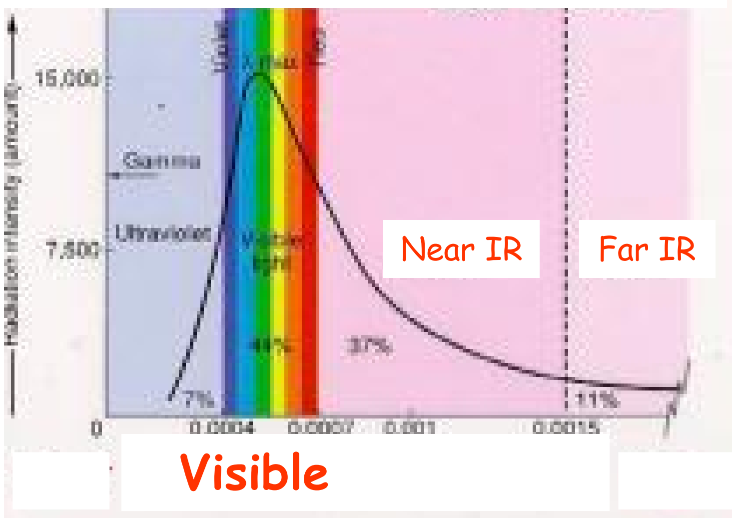
Spectral Absorption of common in water optical constituents, Mean Extraterrestrial Irradiance, and spectral transmittance of the atmospheric constituents, Oxygen and Water Vapour (IRS P4 OCM bands are highlighted)



Sun spectrum

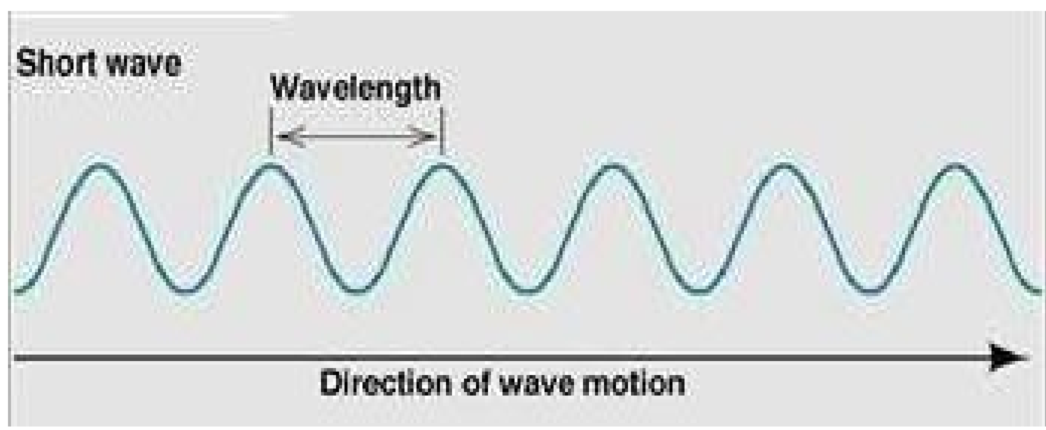
Recall: Each body with some temperature emits radiation. We feel the radiation emitted from our bodies as heat.
This law applies to all objects in the Universe.

Solar spectrum



The Sun emission peaks in the visible range.

The sun is a celestial body with a temperature of 6000 ^oC. Objects with such high temperature emit energy at the short wavelengths of the electromagnetic spectrum visualized as:



Under water light field

•Human eye sensitive: ***400-700nm.***

• EMR is in indivisible units: photons/quanta

•Speed of light **$3x10^8$ m/s**(continuum of photons)

•In day light (bright summer)1 Sq meter of sea surface receives **10^{21}quanta/s** of visible light

•Relation of ª = c/¬ **c** in meters, ª in meters, ¬ in cycles/s

• Energy :£ = hc / ν h = 6.63 x 10^{-34} Js

Photon of energy for a given wavelength

£ = (1988/ ª) 10^{-19} J

energy is in Watts or Js

Radiation flux in (Φ) in **W conversion to quanta/s**

q/s= 5.03 x Φ x ª x **10^{15}** **For a given wavelength band conversion from quanta to W is difficult.**

for 400-700 nm (Q: W) or W to q/s is

2.77 x 10^{18} q/s/w (2-5% accuracy) (Morel & Smith 1974)

Refractive Index

Light travels slowly in any media to vacuum

Light velocity in media

= **light in vacuum/ Refractive index of medium**

RI of air = 1.00028 (assumed as 1)

RI of water = 1.33 (natural water). Varies with T, S and a

C in water = 2. 25x 10^8 m/s.

Frequency remains but λ diminishes in proportion to velocity

Properties of radiation field

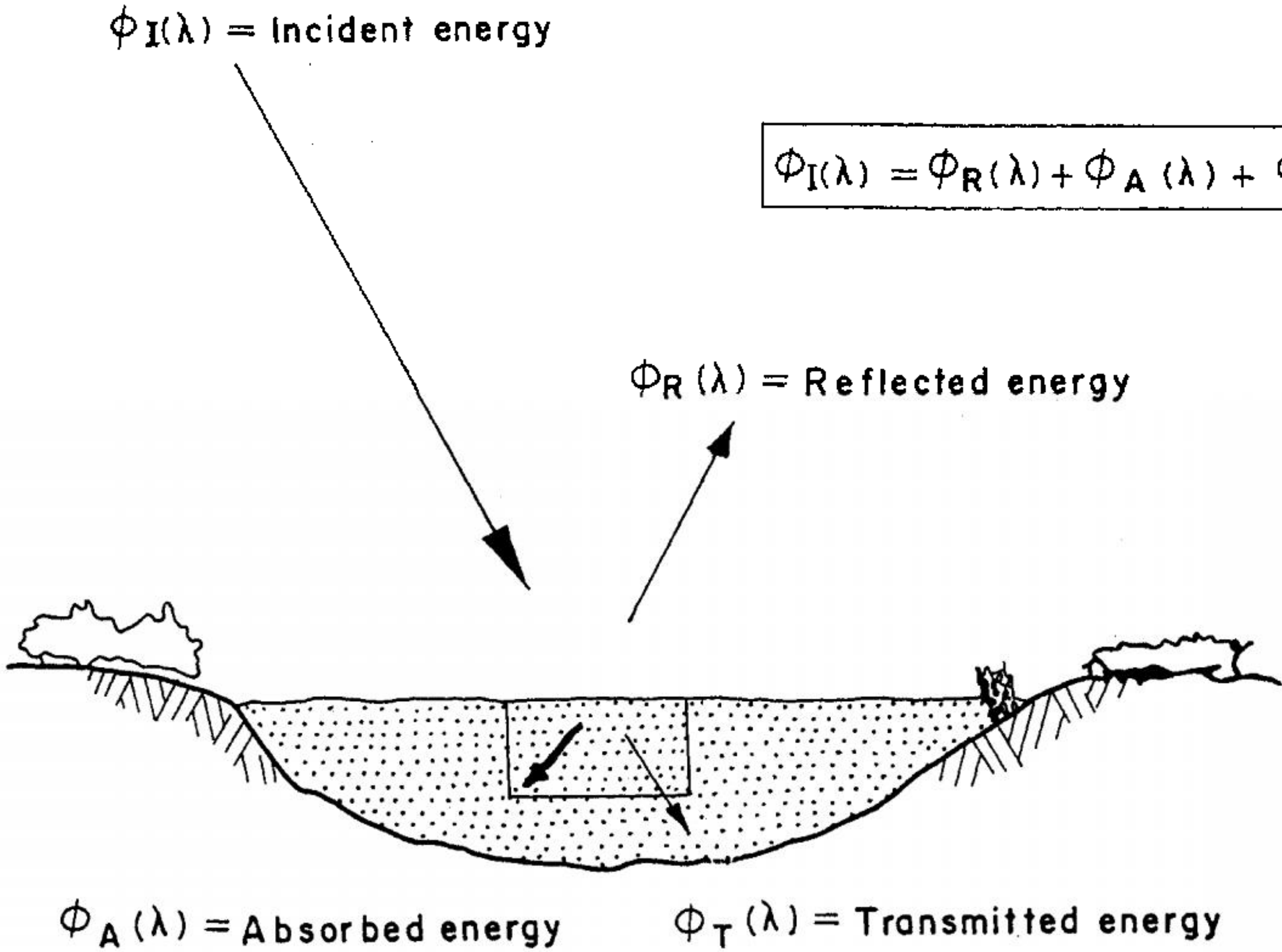
- IAPSO defined the definitions
- Zenith angle(¯): Angle between light beam to upward vertical
- Azimuth angle(ϕ) = Angle between vertical plane incorporating the light beam to some other vertical plane (to vertical plane of Sun)
- Nadir angle: Angle between a given light beam to the downward vertical

- Radiant flux : Φ rate of flow of radiant energy in W (J/s) or in quanta/s
- Radiant Intensity: I flux per unit solid angle in specified direction. An infinitesimal cone in given direction / the element of a solid angle.
- $I = d\Phi / dw$ in W or in (quanta/s) / steradian
- Radiance : L radiant flux per unit solid angle per unit Area of a plane Right angles to the direction of flow . Function of Direction (zenith and Azimuth angles)

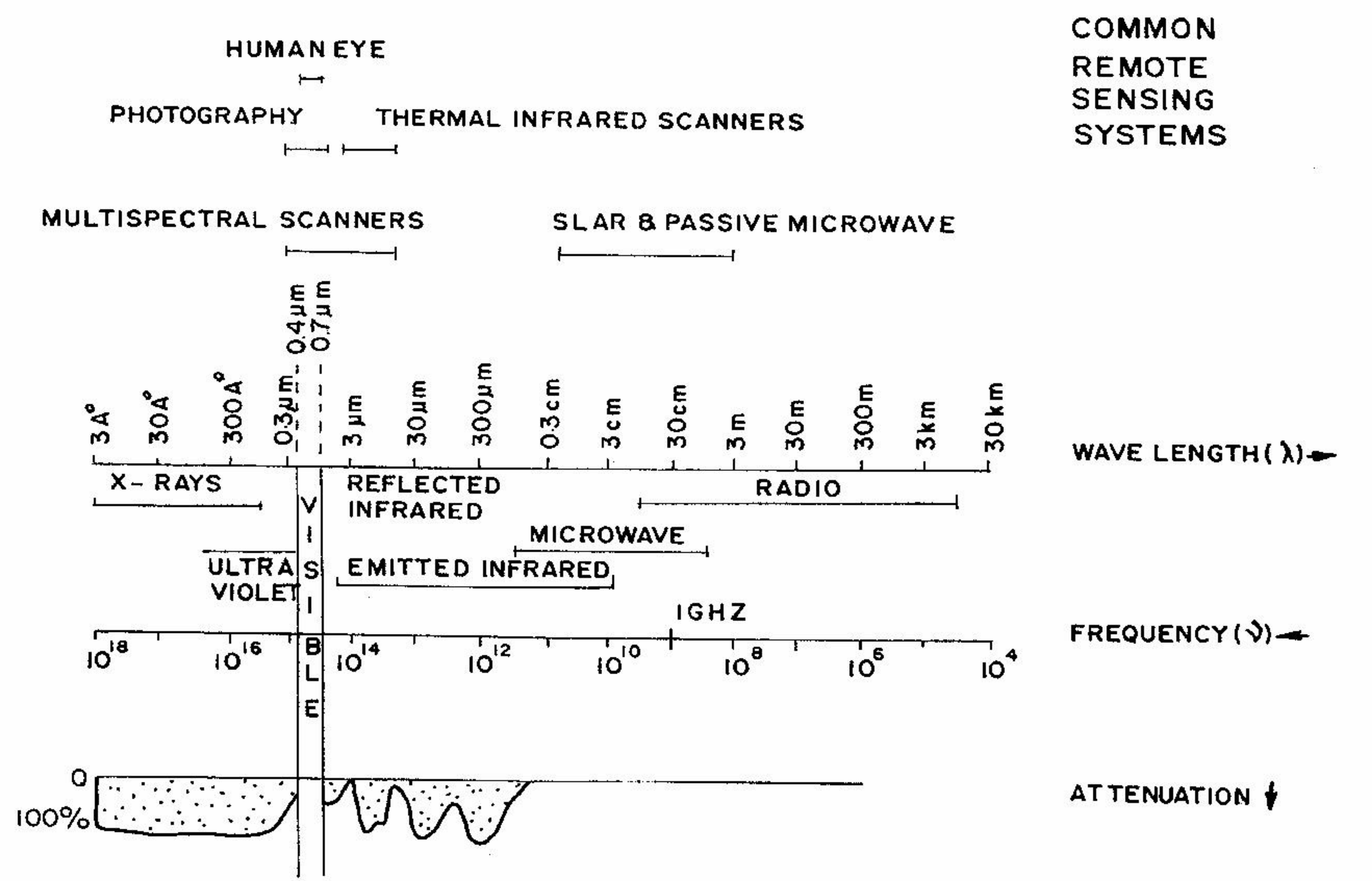
$$L(\theta, \phi): = d^2\Phi / d A \cos(\theta)\, dw,$$

- Irradiance : $E = d\Phi / d A$ (at point of source)W/m2
- Downward irradiance &upwardirradiance(E_d&E_u)

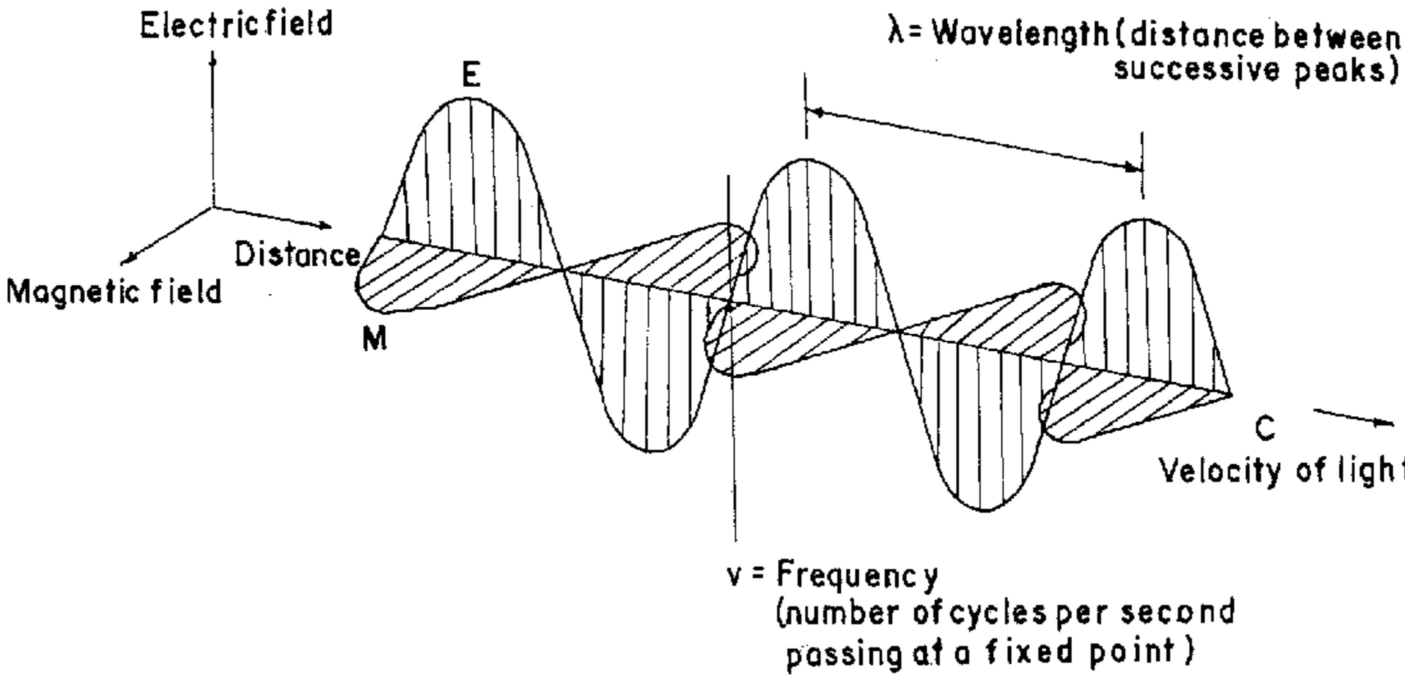
Energy exchange processes in the natural environment (after Lillesand and Kiefer, 1987)



Electromagnetic Spectrum (after curran, 1988)



An Electromagnetic wave and its components
(after Lillesand Kiefer, 1987)



Energy :£ = hc / ν   h = 6.63 x 10-34 Js

ª = **c/¬**   **c** in meters, ª in meters, ¬ in cycles/s

Stefan-Boltzmann Law

All matters at temperatures above absolute zero (0o K or - 273.16oC) continuously emit electromagnetic radiation.

The total energy radiated by an object at particular temperature is given by Stefan- Boltzmann Law, which states that

$$M = \pm T^4$$

where M is total radiant exitance from the surface of the material (Watts/m2); s is Stefan-Boltzmann constant, 5.6697x10-8- W/m2 / oK4 ; T is absolute temperature in ok of the emitting material.

Wien's Displacement Law

The dominant wavelength, or wavelength at which a blackbody radiation curve reaches a maximum, is related to its temperature by Wien's Displacement Law.

$$a_m = \frac{A}{T}$$

where λm is wavelength (µm) corresponding to maximum spectral radiant exitance

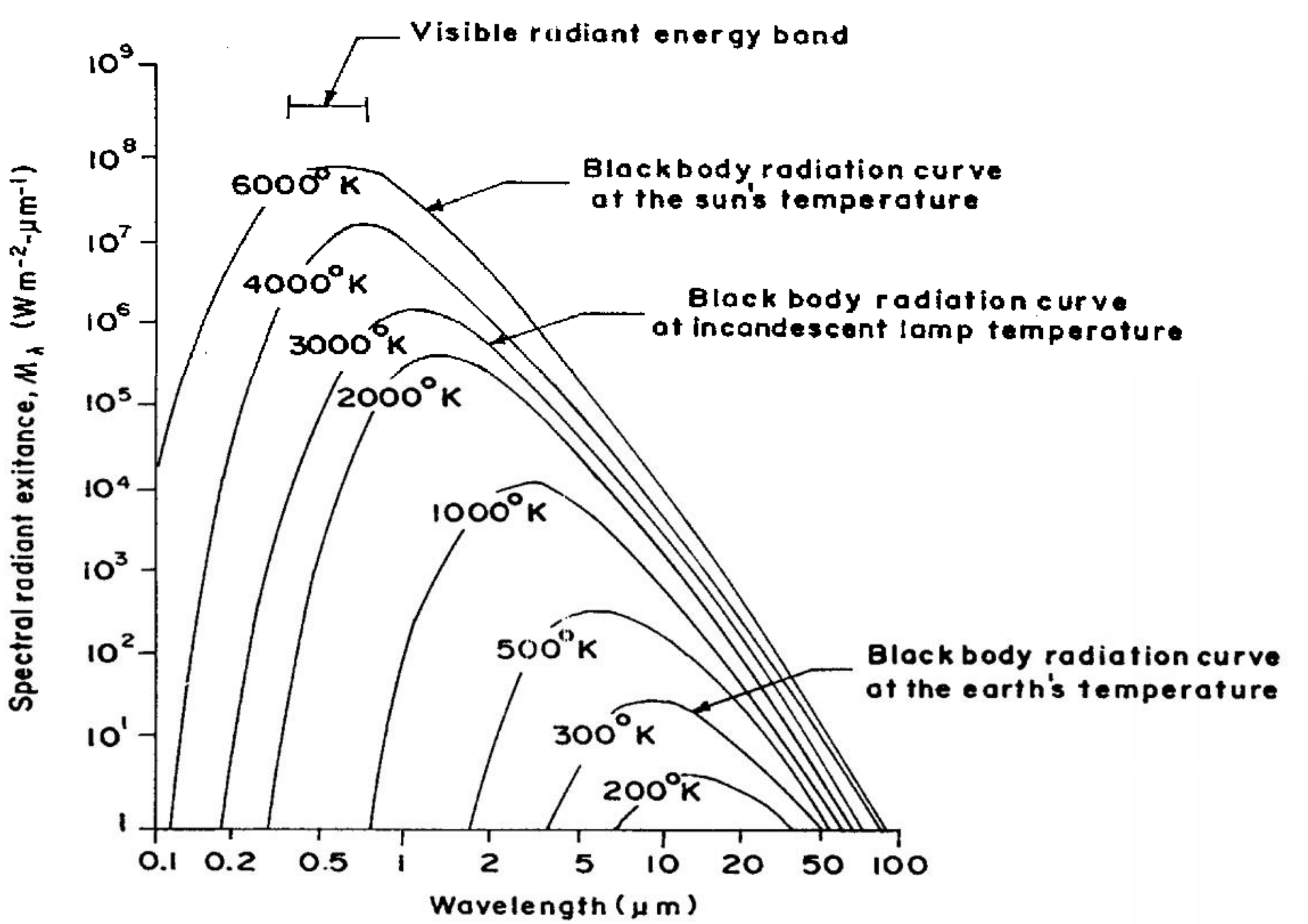
A is a constant with value of 2898 µm. oK; and T is temperature of the blackbody in oK.

Planck's Law

The spectral radiant exitance Mλ, i.e., the total energy radiated in all directions by unit area in unit time in a spectral band for a blackbody is given by Planck's law:

$$M_{a} = \frac{2®hc^{2}}{a^{5}} \frac{1}{e^{\frac{hc}{a kT}} - 1}$$

Spectral distribution of energy radiated by black bodies of various temperatures (after Lillesand and Kiefer, 1987)

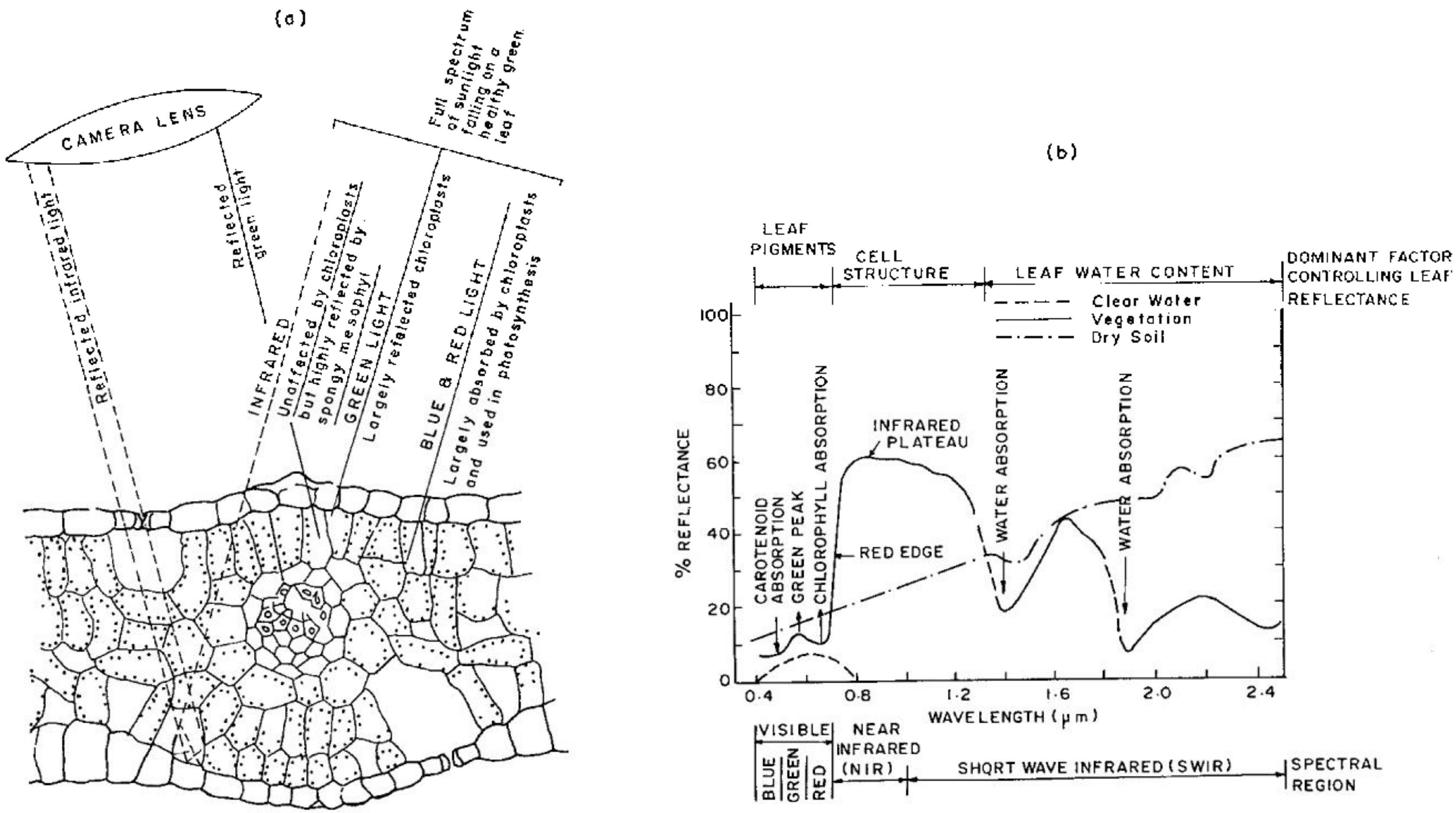


INTERACTION OF EMR WITH EARTH SURFACE FEATURES

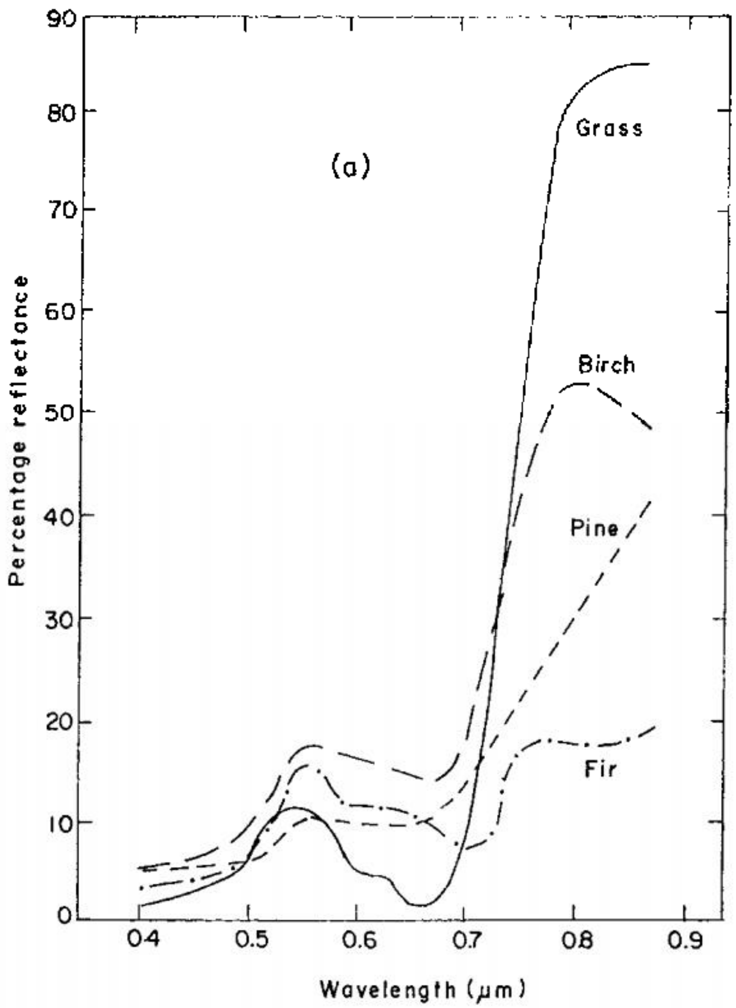
THE REFLECTANCE FROM VEGETAION IS GOVERNED BY

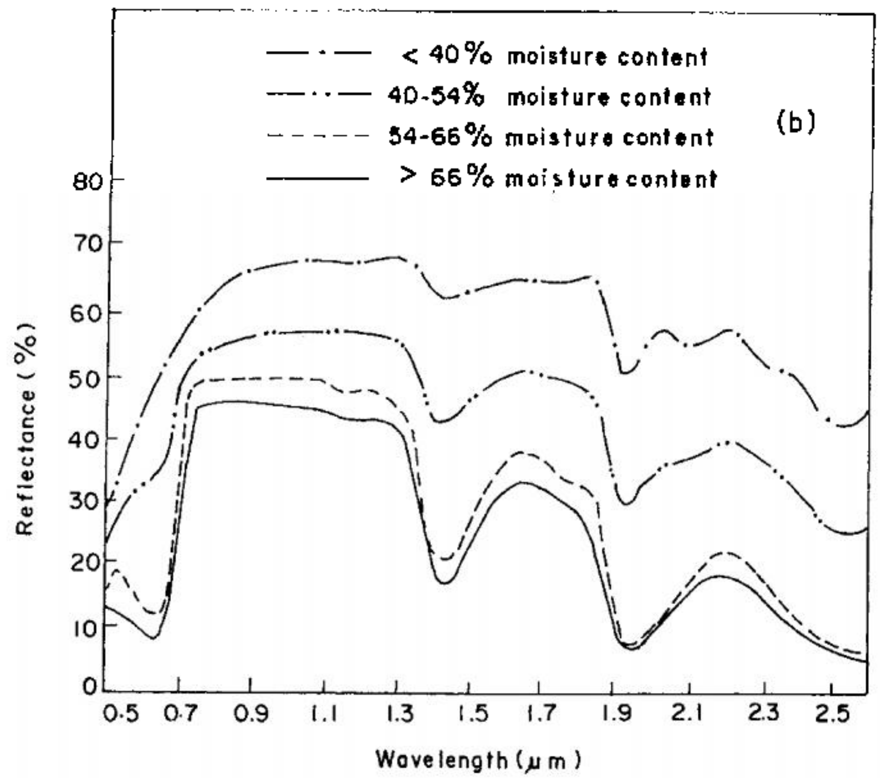
- LAEF PIGMENT (Chlorophyll, Carotinoid etc.)
- LAEF CEL STRUCTURE
- LEAF MOISTURE
- CROWN ARCHITECTURE
- PLANT PHYSIOLOGY

Structure of plant leaf and (b) a typical reflectance curve of green vegetation in the visible , near infrared and mid infrared region (after Goetz et al, 1983)



Spectral Response for (a) different canopies in visible and near IR (after Brooks, 1972) (b) for corn leaves under various moisture content (after Hoffer and Johannsen, 1969)



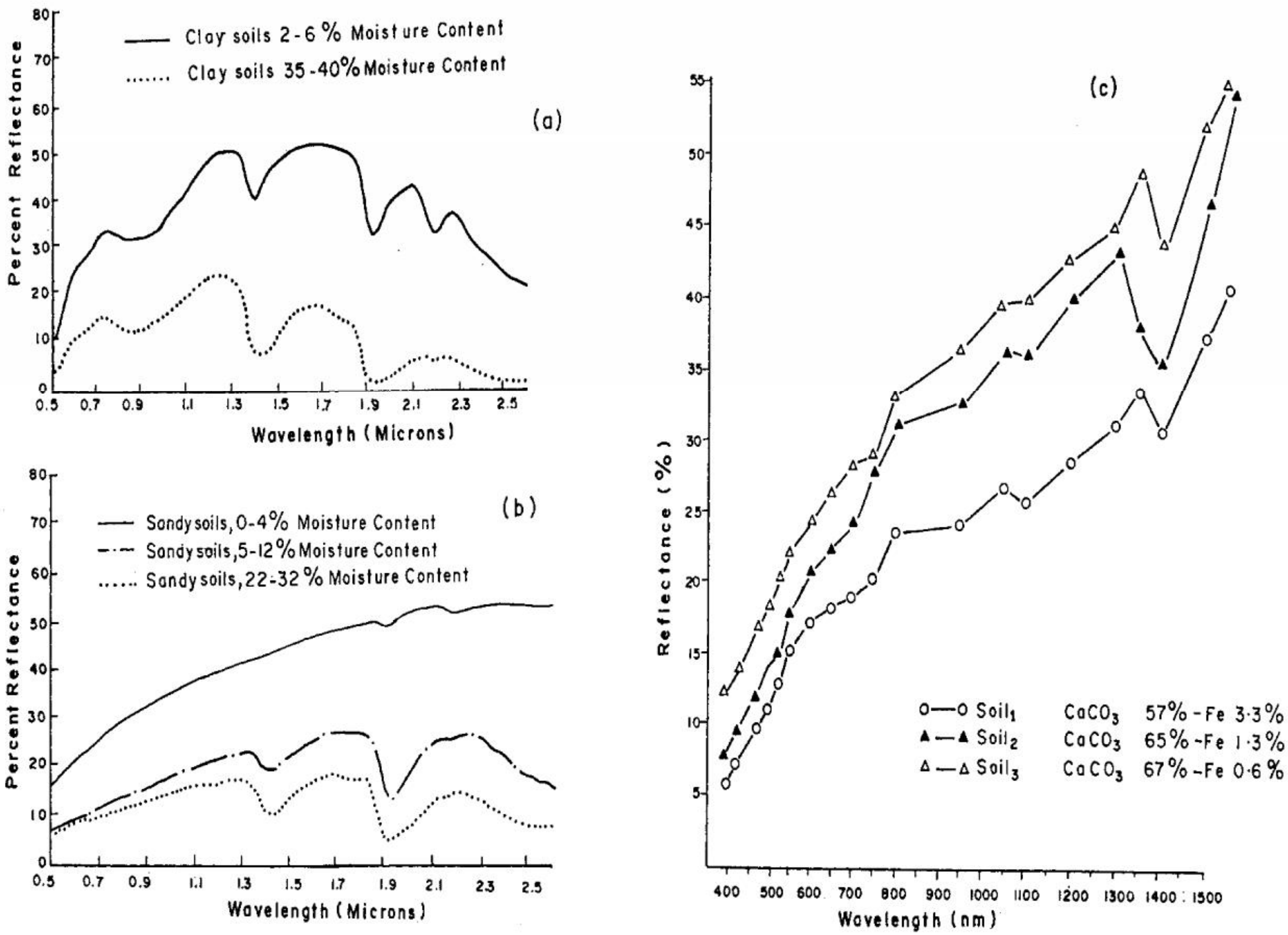


THE REFLECTANCE FROM SOIL IS GOVERNED BY

SOIL IS FORMED BY DISINTEGRATION OF ROCKS THROUGH VARIOUS PROCESSES

- SAND, SILT & CLAY COMPOSITION
- SOIL MOISTURE
- SOIL TEXTURE, COLOUR, GRAIN SIZE
- MINARAL COMPOSITION
- SURFACE ROUGHNESS

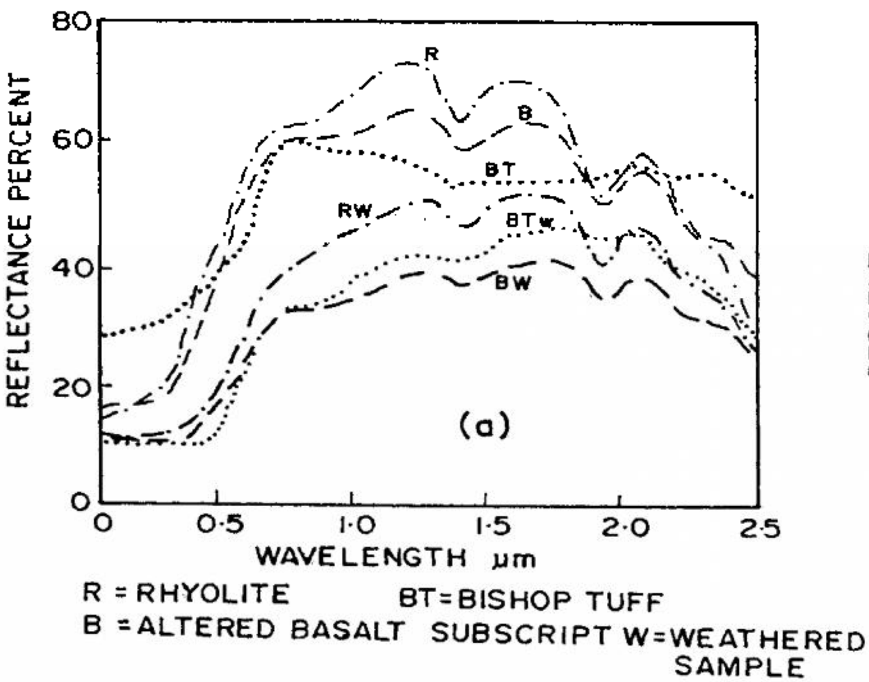
Soil reflectance for (a) Clay soils for two moisture levels, (b) Sandy soils for three moisture levels (after Myers, 1975), and (c) Soil with different composition

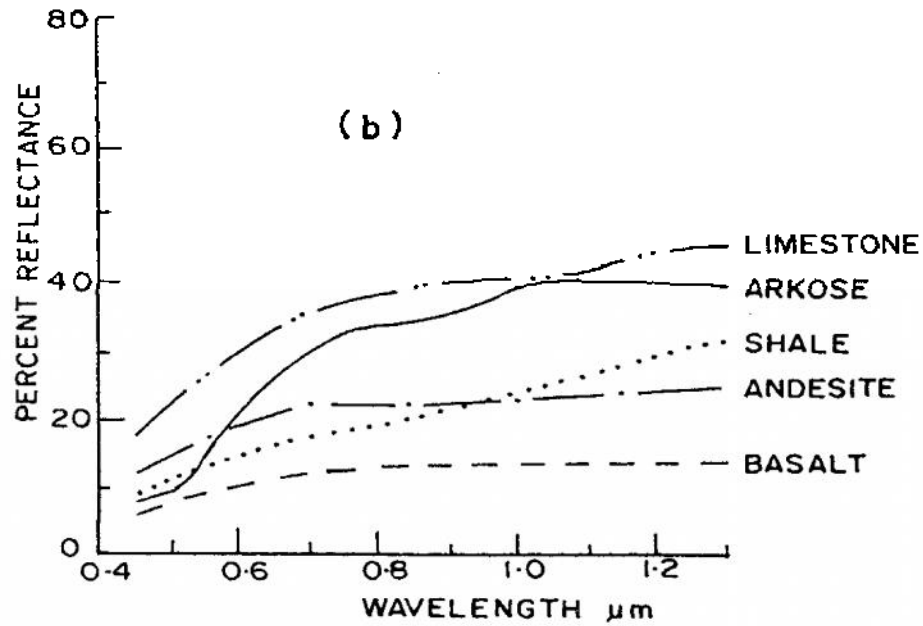


THE REFLECTANCE FROM ROCKS

- NATURE OF ROCK (IGNEOUS, SEDIMENTORY)
- TOP COVR (SOIL, VEGETATION, MIXED-RESPONSE)
- TOPOGRAPHY/ SHADOW
- SURFACE ROUGHNESS

Spectral reflectance characteristics of (a) fresh and weathered rocks (after Lyon, 1970) and (b) Volconic and sedimentary rocks (after Goetz, 1976)

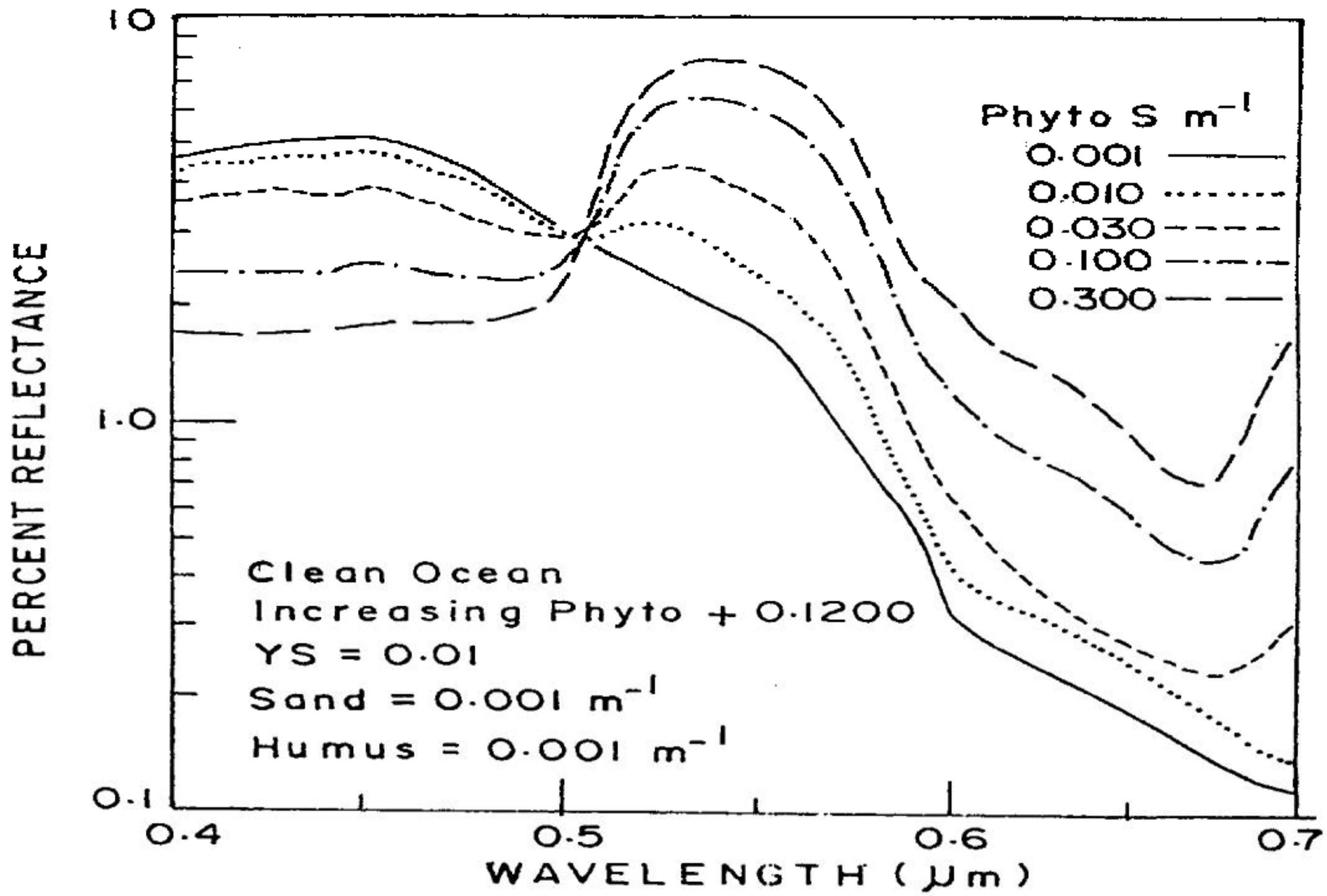




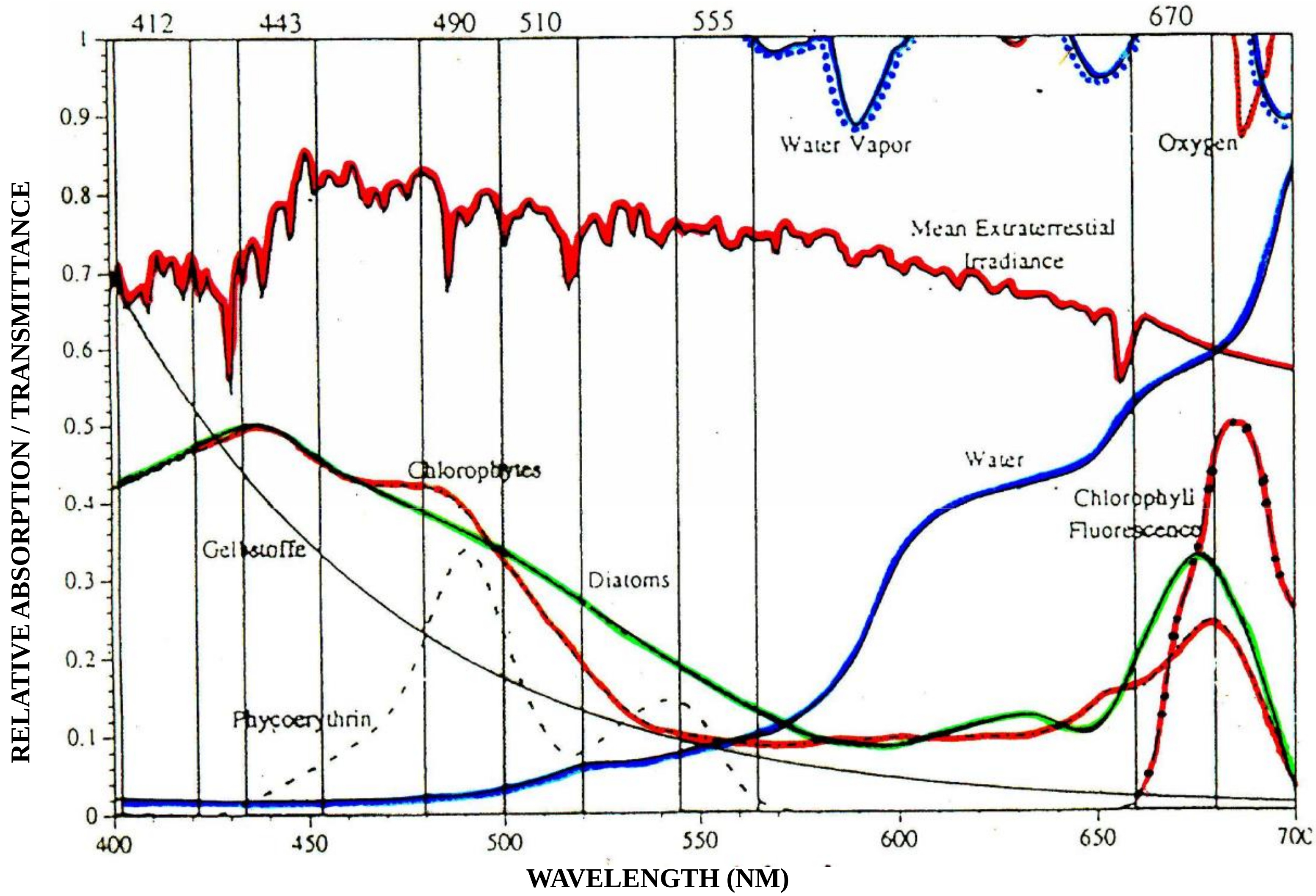
THE REFLECTANCE FROM WATER

- DEPTH
- SUSPENDED PARTICLES IN WATER
- FLOATING VEGETATION, IF ANY
- SUN ANGLE

Effect of increasing phytoplankton concentrations (After Suits, 1973)



SPECTRAL SIGNATURES



Characteristics of present Ocean colour sensors

Sensor	OCM	MODIS	SeaWiFs	MERIS
Orbital Inclination	98.3	98.2	98.2	98.5
Equatorial Crossing Time(h)	12:00	10:30	12:00	10:00
Altitude(Km)	720	705	705	800
Resolution at Nadir(Km)	0.36	1.0	1.1	1.2/0.3
Swath(Km)	1420	2330	2800	1150
Tilt(degree)	ï20	No	ï20	No
Direct Link	X-band	X-band	L-band	X-band
Recorded	Yes	X-band	S-band	X-band
Solar Calibration	Yes	Yes	Yes	Yes
Lunar Calibration	No	Yes	Yes	No
Lamp Calibration	No	Yes	No	No

Differences between OCM and MODIS

OCM

Center ([a] nm)	FWHM (Band pass,nm)	NEaL $Wm^{-2}sr^{-1}um^{-1}$
412	20	0.26
443	20	0.22
490	20	0.17
510	20	0.17
555	20	0.15
670	20	0.10
765	40	0.05
865	40	0.08

MODIS

Center ([a] nm)	FWHM (Band pass,nm)	NEaL $Wm^{-2}sr^{-1}um^{-1}$
412	15	0.048
443	10	0.032
488	10	0.025
531	10	0.018
551	10	0.019
667	10	0.008
680	10	0.007
748	10	0.009
870	15	0.006
469*	20	0.145
555*	20	0.127
645**	50	0.170
858**	35	0.123

* Spatial resolution 0.5 Km

** Spatial resolution 0.25 Km

RETRIEVAL OF SEA SURFACE TEMPERATURE AND POTENTIAL FISHING ZONE MAP PREPARATION

The idea of remote measurement of the surface temperatures of an object stems from Planck's law.

The spectral radiance of a perfect emitter (Black body) at an absolute temperature T in the spectral band with wave number ¬ (cm^{-1}) is given by Planck's function, (¬,T), mW/m^2 Sr cm^{-1}.

$$(\neg,T) = C_1 \neg^3/[\exp(C_2 \neg/T) - 1] \quad \ldots \quad 1$$

Where C_1 and C_2 are known as Planck's radiation constants.

$$C_1 = 1.191066 \times 10^{-5} \ mW/(m^2 \ Sr \ cm^{-1})$$

$$C_2 = 1.438833 \ Cm \ K.$$

For a real object having emittance £, the spectral radiance is given by (¬,T) *£.

Application of Planck's radiation for remote measurement of the Sea Surface Temperature(SST) using Air/Satellite borne Infra-Red (IR) detectors is well known today.

The radiance received at the satellite sensor I(¬) may be written as:

$$I(\neg) = I_e(\neg) + I_{sc}(\neg) + I_r(\neg) + I_{em}(\neg) \quad \dots \quad 2$$

Where

$I_e(\neg)$= **Contribution due to emission from the surface the earth/oceans.**
$I_{sc}(\neg)$= **Contribution due to Scattering process by the atmospheric constituents.**
$I_r(\neg)$= **Contribution due to reflection at the sea surface.**
$I_{em}(\neg)$= **Contribution due to emission from the atmospheric gases.**

In the thermal Infra-Red region, which is of interest to us, the Scattering effects can be ignored for clear atmospheric conditions because the wave length of the radiation (say 3-100 «m) is much larger than the sizes of the molecules (0.0001 «m) or the aerosol particles (0.01-10 «m). Hence $I_{sc}(\neg) = 0$.

The contribution from the solar radiation reflected at the sea surface is about ten times smaller than the digitization error in the 10.5-12.5 «m window region. Therefore, for all practical purposes, the solar radiation reflected at the surface in the thermal channels can safely ignored ($I_r(\neg) = 0$).

Then the Equation 2 cab written as:

$$I(\neg) = I_e(\neg) + I_{em}(\neg) \qquad \dots \qquad 3$$

The NOAA-AVHRR data are being processed regularly at NRSA for the retrieval of Sea Surface Temperatures (SSTs). The processing steps are as follows:

1. **Radiometric Calibration**
2. **SST computation for cloud free areas**
3. **Geometric corrections**
4. **Generation of Potential Fishing Zone (PFZ) maps**
5. **Computation of grid averages**

SST Computation:

SSTs are computed for cloud free pixels using the following equation:

$$SST(0C) = a*T_{b4} + b*(T_{b4} - T_{b5}) + c*(T_{b4} - T_{b5})*Sec(¯) + d$$

Where T_{b4} and T_{b5} are the brightness temperatures of AVHRR channels 4 and 5 respectively and ¯ is satellite zenith angle and is given below:

$$¯_{I} = Sin^{-1}[\{(R + h)/R\}*Sin\ ¤_{I}]$$

R = Radius of the Earth (6378.388 Km)

h = Height of the satellite (833 Km)

$¤_{I}$ = Look angle at ith pixel

$$¤_{I} = -55.4 + (55.4/1024)*I$$

SSTs are computed when satellite zenith angle is less than 53 degrees

The regression coefficients a, b, c and d for different satellites are used as follows:

Satellite	a	b	c	d
NOAA-11	0.979224	2.361743	0.33084	-267.029
NOAA-11 (1-4-91)	1.02455	2.45	0.64	-280.67
NOAA-12	0.963563	2.579211	0.242598	-263.006
NOAA-14	1.017342	2.139588	0.779706	-278.430

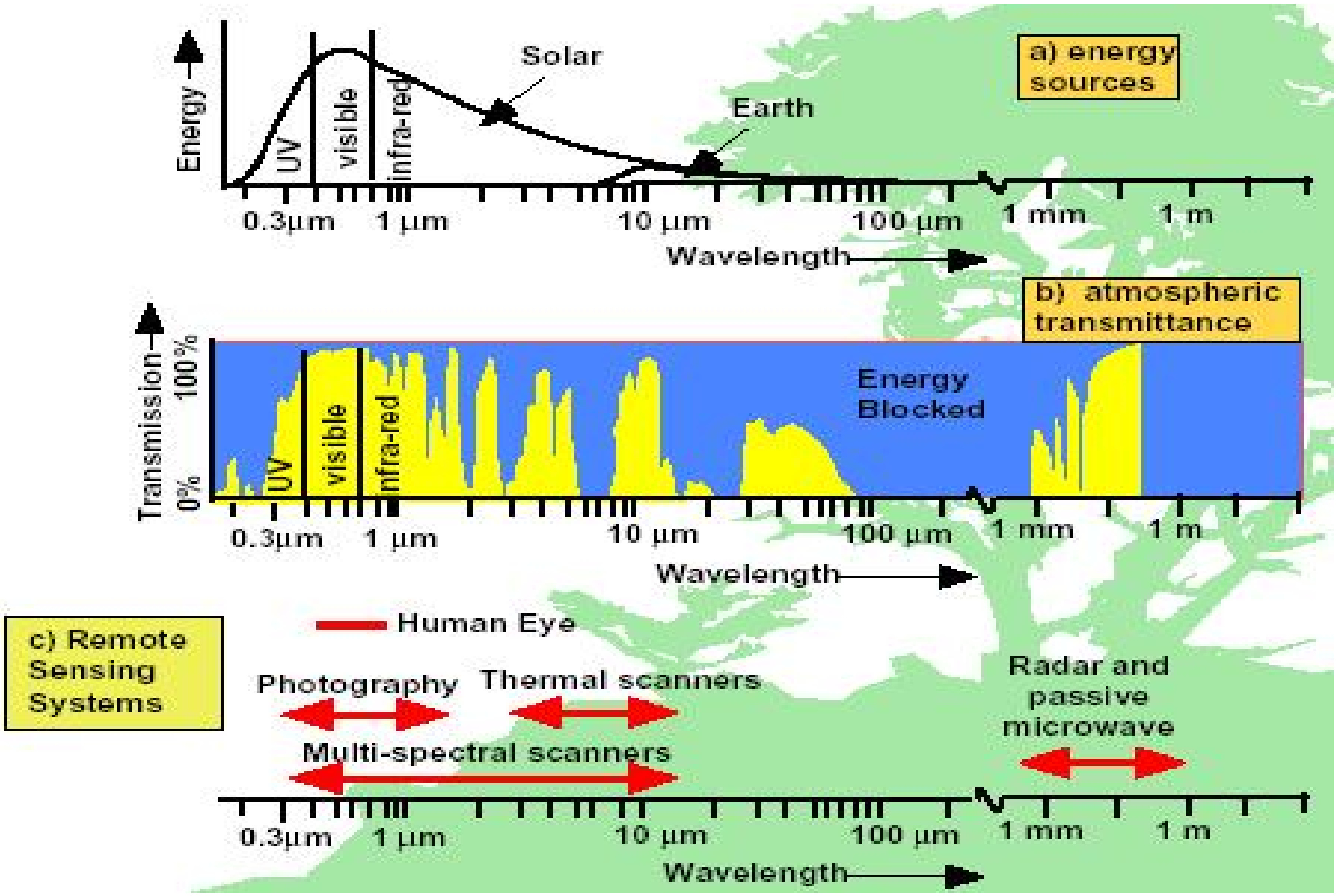
Ocean phenomena detectable readily from IR SST images

Phenomenon	Magnitude (^{O}C)	Length scale (km)	Time scale	Process required
SST distribution in ocean basins	35	1000-10 000	-	SST map
Seasonal variation of the SST distribution with ocean basins	20	1000-10 000	1month-1 year	Monthly SST map sequence
Intra and inter annual variation of SST distribution (e.g.EL Nino)	0.5-5	500-5000	Months-years	Monthly sequence of SST anomalies
Tropical monsoon events	0.5-5	200-2000	2weeks-1year	Weekly sequence of SST maps
Oceanic planetary (e.g.Rossby) waves	0.2-3	200-10 000	Months-years	Hovmuller plots of SST anomalies
Tropical instability waves	0.5-5	200-2000	1week-4months	Hovmuller plots of SST anomalies
Major ocean fronts	0.5-5	10-2000	1month-years	SST maps
Western boundary currents	1-8	5-2000	-	SST maps
Meanders and eddies on boundary and ocean currents	1-8	5-2000	2 weeks- 6 months	weekly sequence of SST maps
Oceanic mesoscale eddies	0.5-5	20-500	weeks	SST map as series
Major ocean upwelling regions	1-5	10-1000	weeks	SST map series
Deep convection cooling events	0.2-2	10-200	Days	SST anomalies
Major river plumes in the ocean	0.2-2	50-1000	-	SST maps
Coral bleaching events	0.3-3	20-200	Days	SST anomalies
Diurnal warming events	0.5-5	5-200	1-12hr	SST anomalies
Local wind Mixing phenomena	0.2-2	5-500	hours	SST map series
Shelf edge mixing phenomena	0.2-2	2-200	Days	SST map series
Shelf sea tidal mixing fronts	0.5-5	2-200	Days	SST ma series
Shelf sea circulation and mixing	0.2-5	1-500	Days	SST map series
Regions of freshwater influence	0.1-1	1-50	Days	SST map series
Coastal wind induced phenomena	0.2-2	1-100	Hours	SST ma series

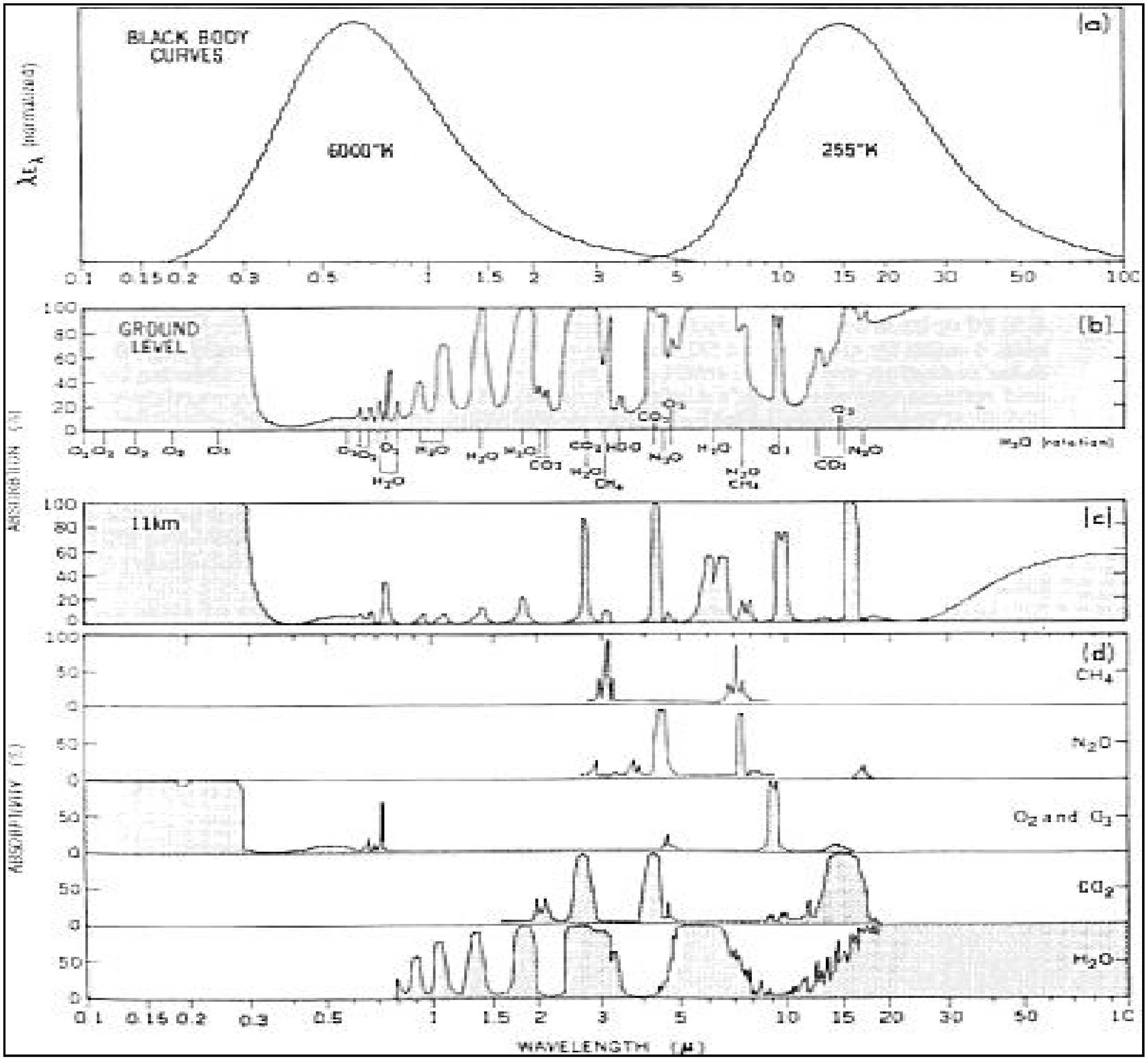
CURRENT SPACEBORNE SENSORS FOR SST

Satellite	Sensor	Resolution	Accuracy
NOAA	AVHRR	1 km	0.5 K
METOP	AVHRR	1km	0.2 K
ENVISAT	AATSR	1 km	<0.5 K
TRMM	TMI	25 kms	0.6 K
	VIRS	2 kms	0.4 K
TERRA	MODIS	1 km	<0.5 K
AQUA			
AQUA	AMSR-E	58 & 36 km	<0.6 K
GOES		4 km	0.7 K
INSAT-3A/KALPANA		8 km	
METEOSAT		5 km	
MSG	AVHRR	1 km	<0.5 K
INSAT-3D	Imager	4 km	<0.5 K

Solar Radiation Spectrum & Absorption by Atmosphere



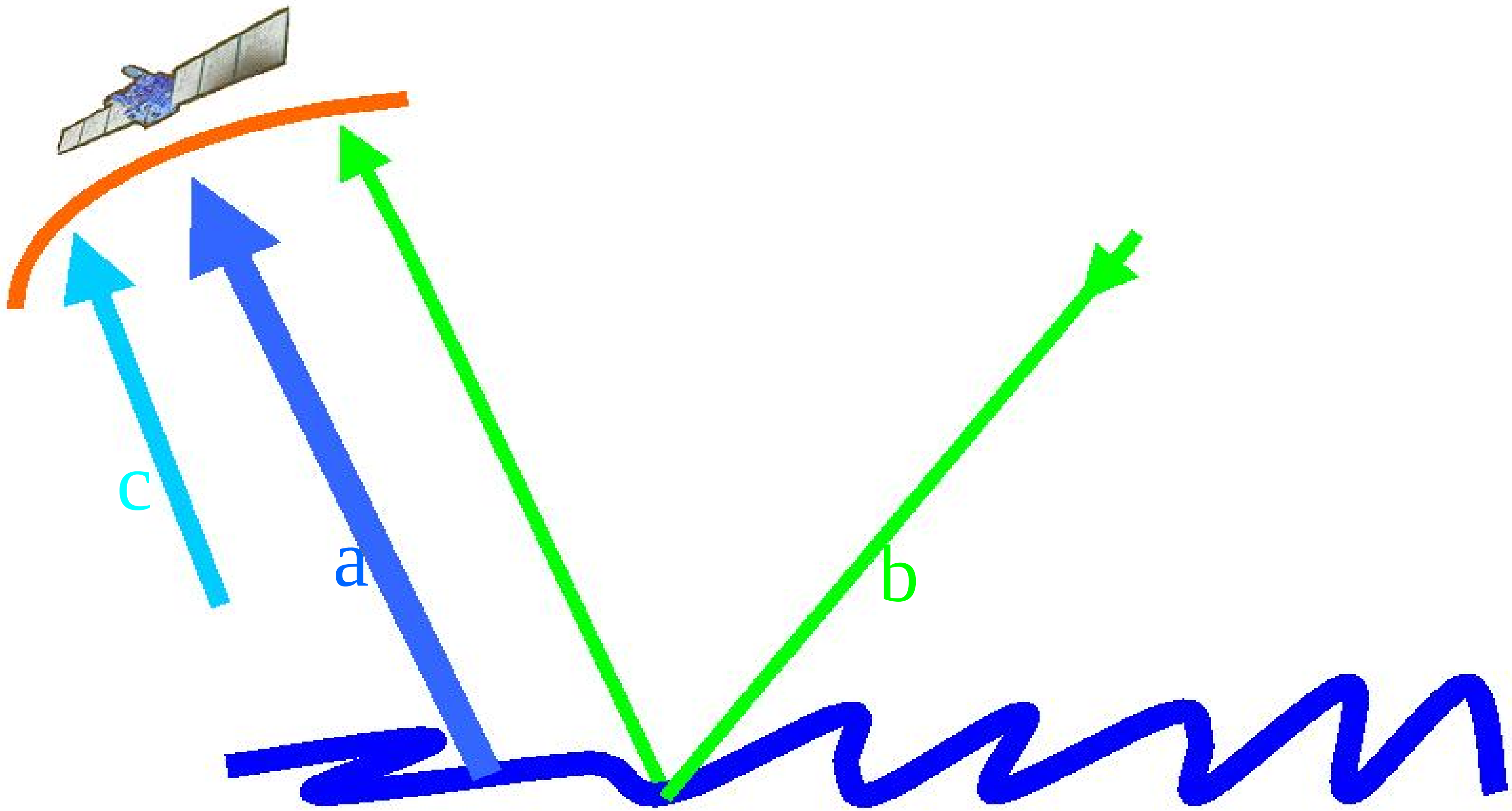
EM SPECTRUM & ABSORPTION LINES



Solar and Terrestrial Radiances

Absorption Lines

Contributions to the IR radiation received at the sensor



$$I_{sat} = I_a + I_b + I_c$$

a- Signal emitted by the sea surface

b- Downward atmospheric emission, reflected at sea surface

c – Direct upward atmospheric emission

RADIATIVE TRANSFER

RADIANCE RECEIVED BY AN EARTH-VIEWING RADIOMETER

a c b

$$I({}^{3},{}^{-}) = Isea({}^{3},{}^{-}) + Iatm({}^{3},{}^{-}) + Iatmr({}^{3},{}^{-})$$

$$Isea({}^{3},{}^{-}) = \pounds({}^{3})\,{}^{2}({}^{3},0,Z,{}^{-})B({}^{3},SST)$$

$$Iatm({}^{3},{}^{-}) = \int_{0}^{\infty} I({}^{3},z)\,{}^{2}({}^{3},z,\infty,{}^{-})dz$$

$$Iatmr({}^{3},{}^{-}) = (1-\pounds({}^{3}))\,{}^{2}({}^{3},0,\infty,{}^{-})\int_{0}^{\infty} I({}^{3},z)\,{}^{2}({}^{3},0,z,{}^{-})dz$$

$${}^{2}({}^{3},z1,z2,{}^{-}) = \exp[-\sec{}^{-}\int_{z1}^{z2}\sim({}^{3},u)du]$$

ν= frequency
θ= incidence angle
α= atm. absorption
ε= surface emissivity
τ= atm transmittance
z= altitude

RADIATIVE TRANSFER (continued)

RADIANCE EMITTED BY A THIN ATMOSPHERIC LAYER

$$I(\nu, z)\Delta h = B\{\nu, T(z)\}\varepsilon_a(\nu, z)\Delta h$$

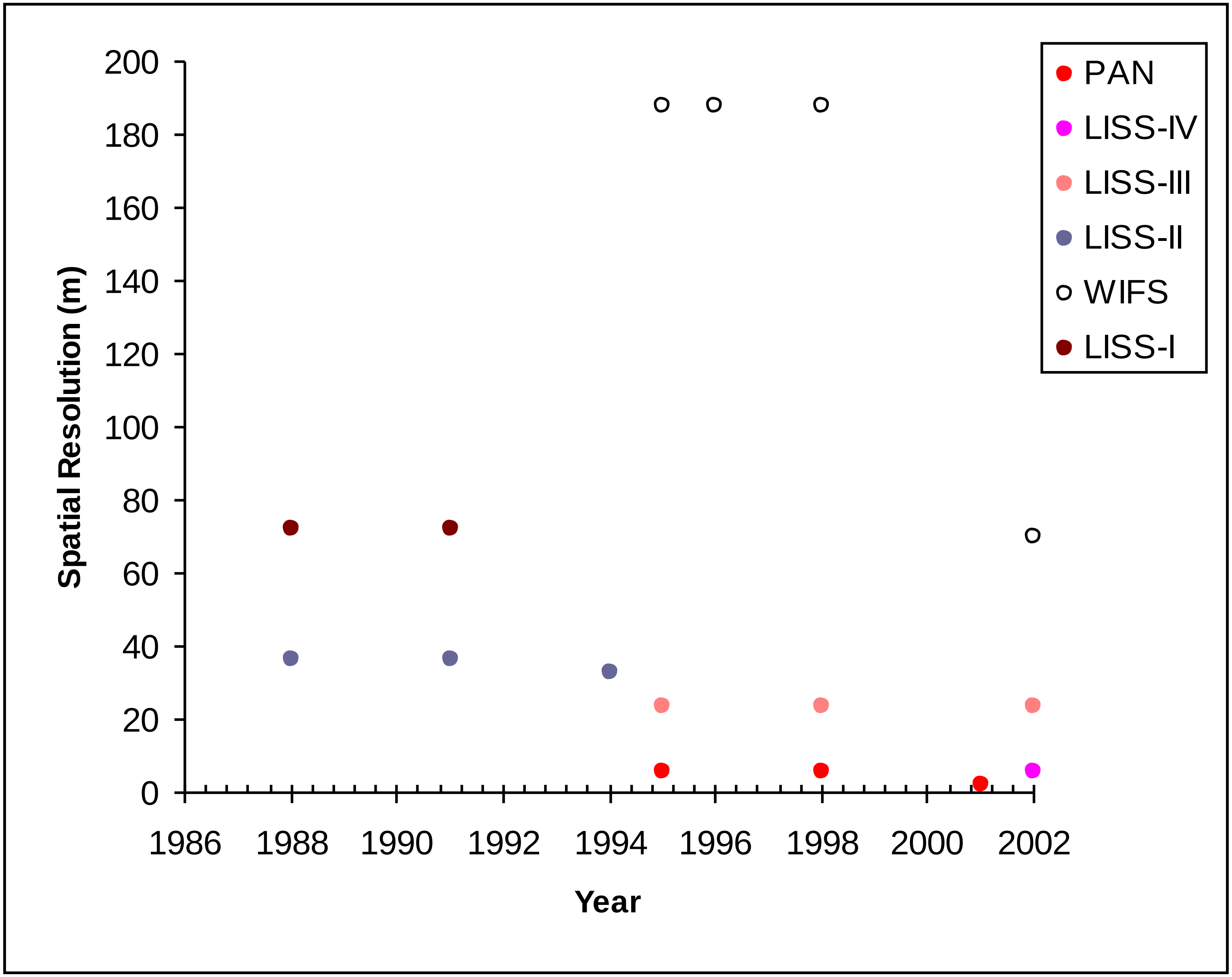
$$B(\nu,T)=2h\nu^3/[c^2(e^{h\nu/kT}-1]$$

B= Planck's Function
t=atm layer temperature
h= Planck's constant
k= Boltzman's constant
ϕ= channel response function
ν1,ν2= channel freq limits

$$Iatm(\nu, \theta) = \int_0^\infty B\{\nu, T(z)\}\varepsilon_a(\nu, z)\tau(\nu, z, \infty, \theta)dz$$

INTEGRATED RADIANCE OVER CHANNEL BANDWIDTH

$$Ii = [\int_{i=\nu 1}^{i=\nu 2} I(\nu, \theta)\phi_i(\nu)d\nu] / [\int_{i=\nu 1}^{i=\nu 2} \phi_i(\nu)d\nu]$$



EVALUATION OF INDIAN REMOTE SENSING SATELLITE FOR COASTAL STUDIES

RADIATIVE TRANSFER (continued)

RADIANCE EMITTED BY A THIN ATMOSPHERIC LAYER

$$I(^3, z)¢h = B\{^3, T(z)\}\sim_a(^3, z)¢h$$

$$B(\nu,T)=2h\nu^3/[c^2(e^{h\nu/kT}-1]$$

B= Planck's Function
t=atm layer temperature
h= Planck's constant
k= Boltzman's constant
ϕ= channel response function
$\nu1,\nu2$= channel freq limits

$$Iatm(^3, ^-) = \int_0^{\infty} B\{^3, T(z)\}\sim_a(^3, z)^2(^3, z, \infty, ^-)dz$$

INTEGRATED RADIANCE OVER CHANNEL BANDWIDTH

$$Ii = [\int_{i=^3 1}^{i=^3 2} I(^3, ^-)¤_i(^3)d^3]/[\int_{i=^3 1}^{i=^3 2} ¤_i(^3)d^3]$$

REMOTE SENSING SATELLITES AND SENSORS

SATELLITE	SENSORS	NO. OF BANDS	WAVELENGTH (MM)	SPATIAL RESOLUTION	SWATH	LAUNCH DATE
LANDSAT 1, 2, 3	MSS	4	0.5 - 0.6 0.6 - 0.7 0.7 - 0.8 0.8 - 1.1	80 M	185 KM	July 1972 (1) Jan 1975 (2) Mar 1978 (3)
LANDSAT 4, 5	TM	7	0.45 - 0.52 0.52 - 0.59 0.63 - 0.69 0.76 - 0.90 1.55 - 1.75 2.08 - 2.35 10.4 - 12.5	30 M 120 M	185 KM	July 1982 (4) Marc 1984 (5)
SPOT 1, 2, 3	HRV PAN	3	0.50 - 0.59 0.61 - 0.68 0.79 - 0.89 0.51 - 0.73	20 M 10 M	117 KM 117 KM	Feb 1986 (1) Jan 1990 (2) Sept 1993 (3)
IRS - 1A	LISS-I LISS-II	4 4	B1 0.45 - 0.52 B2 0.52 - 0.59	72.5 M 36.25 M	148 KM 2 X 74 KM	Mar 1988
IRS - 1B			B3 0.62 - 0.68 B4 0.77 - 0.86			Aug 1991
IRS-1C IRS-1D	LISS-III PAN WiFS	4 1 2	B2 0.52 - 0.59 B3 0.62 - 0.68 B4 0.77 - 0.86 B5 1.55 - 1.70 0.50 - 0.75 B3 0.62 - 0.68 B4 0.77 - 0.86	23.5 M 5.8 M 188 M	142 KM 70.5 KM 810 KM	Dec 1995 Sept 1997 Steerable $\pm 26^0$
IRS-P 2	LISS-II	4	B1 0.45 - 0.52 B2 0.52 - 0.59 B3 0.62 - 0.68 B4 0.77 - 0.86	32.74 M (Across Track) 37.39 M (Along Track)	130 KM	Oct 1994

SATELLITE	SENSORS	NO. OF BANDS	WAVELENGTH (MM)	SPATIAL RESOLUTION	SWATH	LAUNCH DATE
IRS-P3	MOS-A MOS-B MOS-C WiFS			1570 M 520 M 520 M 188 M	195 Km 200 Km 192 Km 774 Km	Mar 1996
IRS-P4	OCM MSMR	8 4	0.402-0.422 0.433-0.453 0.480-0.500 0.500-0.520 0.545-0.565 0.660-0.680 0.745-0.785 0.845-0.885 6.6,10.65, 18,21GHz	246x360m 120,80,40, 40m	1420 KM	26^{th} May 1999
ERS-1, 2	SAR IMAGE MODE	1	C Band 5.3 GHz	30 M	100 KM	July 1991 (1) April 1995 (2)
JERS 1	SAR	1	L Band 1.275 GHz	18 M	75 KM	Feb 1992
RADARSAT-1	SAR	1	C Band 5.3 GHz	25m x 28m 48 - 30 m x 28 m 32 - 25 m x 28 m 11 - 9 m x 9 m	100 KM 165 KM 150 KM 45 KM	Sept 1995
IKONOS	MSS PAN	4 1	0.45-0.52 0.52-0.60 0.63-0.69 0.76-0.90 0.45-0.90	4.0 m 1.0 m	11 KM	Sept 1999

STATUS ON UTILIZATION OF REMOTE SENSING DATA FOR COASTAL STUDIES

STATUS ON UTILIZATION OF REMOTE SENSING DATA FOR COASTAL STUDIES.

Resources/ Parameters /Processes	Remote sensing compliances	Status
Mangroves, Coral reefs, Salt pans, Aquaculture, Wetlands, Other Coastal Inland Resources	Mapping and Monitoring in different scales	Operational using High Resolution Multispectral sensors Data from IRS series
Fisheries	Forecasting and Monitoring	Semi operational with NOAA and IRS-P4
Minerals & Energy	Exploring and Monitoring	R & D stage with existing RS Data
Coastal Geomorphology and Shoreline changes	Mapping and Monitoring in different scales	Operational High Resolution Data from IRS Series
SST, Winds, Waves, Water vapour content, Cloud liquid water etc.	Fishery forecasting, Monsoons, Ocean and Atmospheric studies	Operational with IRS-P4 and other foreign satellites

STATUS ON UTILIZATION OF REMOTE SENSING DATA FOR COASTAL STUDIES.

Resources/ Parameters /Processes	Remote sensing compliances	Status
Upwelling, Eddies, Gyres etc.	Fishery and Ocean Dynamics studies	Operational with IRS-P4 and other foreign satellites
Coastal Regulation Zone	Mapping and Monitoring in 1: 50,000 and 1: 25,000 scale	Operational using IRS IC & ID data
Suspended Sediments concentration	Mapping and Monitoring	Semi operation with IRS-P4
Oil Slicks	Mapping and Monitoring	Semi operational with IRS-series and other foreign satellites
Chlorophyll Concentration	Mapping and Monitoring	Semi operation with IRS-P4
Currents and Surface Circulation Patterns	Mapping and Monitoring	Semi operational with IRS-series and other foreign satellites

PERFORMANCE OF AIRCRAFT AND SATELLITE REMOTE SENSORS FOR COASTAL ZONE STUDIES

Platform:

AC = Aircraft (Medium & Low Altitude)
SC = Spacecraft (Satellite)

RATING:

3 = RELIABLE (OPERATIONAL)
2 = NEEDS ADDITIONAL FIELD TESTING
1 = LIMITED VALUE (FUTURE POTENTIAL)
0 = NOT APPLICABLE

PERFORMANCE OF AIRCRAFT AND SATELLITE REMOTE SENSORS FOR COASTAL ZONE STUDIES

SENSORS	Platforms	Vegetation and Landuse	Biomass & Veg. Stress	Coastline Erosion
FILM CAMERA	AC	3	1	3
	SC	3	1	2
MULTI SPECTRAL SCANNER	AC	3	3	3
	SC	3	2	2
THERMAL IR SCANNER	AC	1	1	1
	SC	1	0	0
LASER PROFILER	AC	0	0	1
	SC	0	0	1
LASER FLUOROSENSORS	AC	1	0	1
	SC	0	0	0
MICROWAVE RADIOMETERS	AC	1	0	1
	SC	0	0	0
IMAGING RADAR (SAR OR SLAR)	AC	2	1	3
	SC	1	0	2
RADAR ALTIMETER	AC	1	0	1
	SC	0	0	0
RADAR SCATTEROMETER	AC	0	0	0
	SC	0	0	0

PERFORMANCE OF AIRCRAFT AND SATELLITE REMOTE SENSORS FOR COASTAL ZONE STUDIES

SENSORS	Platforms	Coastal Geomorphology	Depth Profiles	Suspend Sediment Profiles	Suspend Sediment Concentration
FILM CAMERA	AC	3	3	3	3
	SC	2	2	2	2
MULTI SPECTRAL SCANNER	AC	2	2	2	2
	SC	1	1	1	1
THERMAL IR SCANNER	AC	2	2	2	2
	SC	1	1	1	1
LASER PROFILER	AC	2	2	2	2
	SC	1	1	1	1
LASER FLUOROSENSORS	AC	3	3	3	3
	SC	2	2	2	2
MICROWAVE RADIOMETERS	AC	3	3	3	3
	SC	2+	2+	2+	2+
IMAGING RADAR (SAR OR SLAR)	AC	3	3	3	3
	SC	2	2	2	2
RADAR ALTIMETER	AC	3	3	3	3
	SC	2 +	2 +	2 +	2 +
RADAR SCATTEROMETER	AC	0	0	0	0
	SC	0	0	0	0

PERFORMANCE OF AIRCRAFT AND SATELLITE REMOTE SENSORS FOR COASTAL ZONE STUDIES

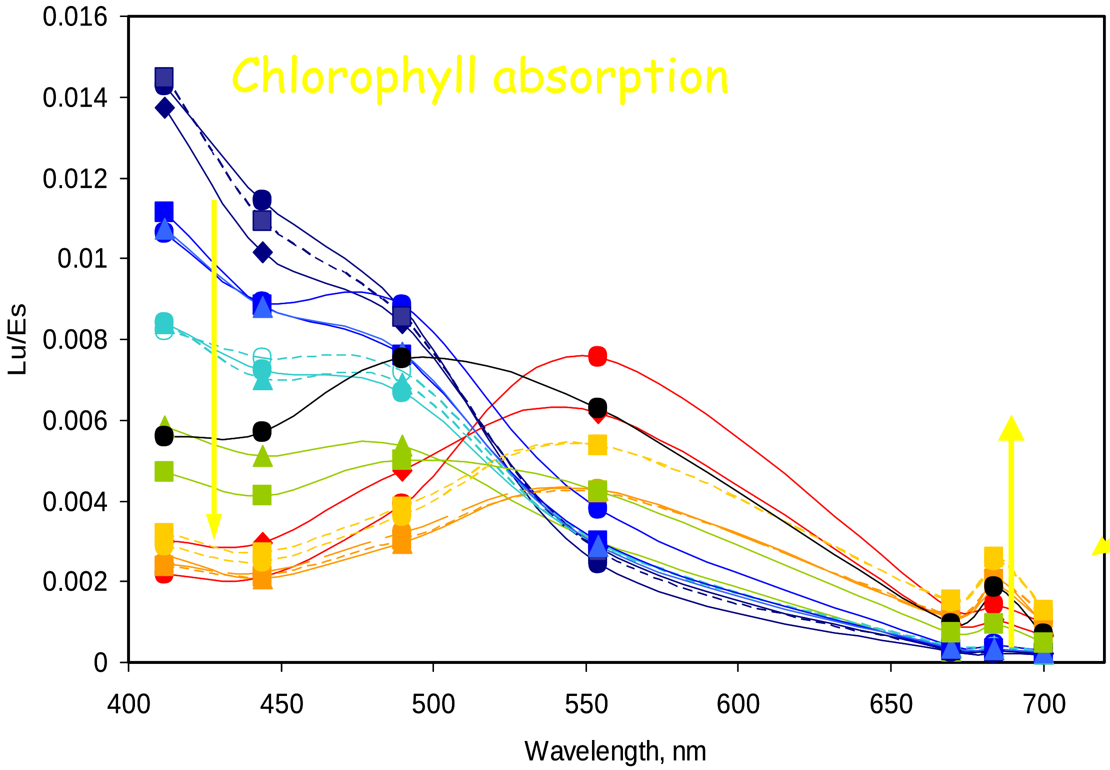
SENSORS	Platforms	Chlorophyll Concentration	Oil Slicks	SST	Water Salinity	Current Circulation Pattern
FILM CAMERA	AC	1	2	0	0	3
	SC	1	1	0	0	2
MULTI SPECTRAL SCANNER	AC	2+	3	0	0	2
	SC	2 +	2	0	0	1
THERMAL IR SCANNER	AC	0	3	3	1	2
	SC	0	1	3	0	2
LASER PROFILER	AC	0	1	0	0	2
	SC	0	0	0	0	1
LASER FLUOROSENSORS	AC	3-	3	1	1	3
	SC	1	1	0	0	2
MICROWAVE RADIOMETERS	AC	1	3	3	2	2
	SC	0	1	2	1	1
IMAGING RADAR (SAR OR SLAR)	AC	0	3	1	1	3
	SC	0	2	0	0	2
RADAR ALTIMETER	AC	0	1	1	1	2
	SC	0	0	0	0	1
RADAR SCATTEROMETER	AC	0	1	0	1	2
	SC	0	0	0	0	0

PERFORMANCE OF AIRCRAFT AND SATELLITE REMOTE SENSORS FOR COASTAL ZONE STUDIES

SENSORS	Platforms	Wave Spectra	Sea State	Surface Winds
FILM CAMERA	AC	3	3	3
	SC	2	2	2
MULTI SPECTRAL SCANNER	AC	2	2	2
	SC	1	1	1
THERMAL IR SCANNER	AC	2	2	2
	SC	2	2	2
LASER PROFILER	AC	2	2	2
	SC	1	1	1
LASER FLUOROSENSORS	AC	3	3	3
	SC	2	2	2
MICROWAVE RADIOMETERS	AC	2	2	2
	SC	1	1	1
IMAGING RADAR (SAR OR SLAR)	AC	3	3	3
	SC	2	2	2
RADAR ALTIMETER	AC	2	2	2
	SC	1	1	1
RADAR SCATTEROMETER	AC	2	2	2
	SC	0	0	0

THANK YOU

PHYTOPLANKTON FLUORESCENCE



Increase in fluorescence