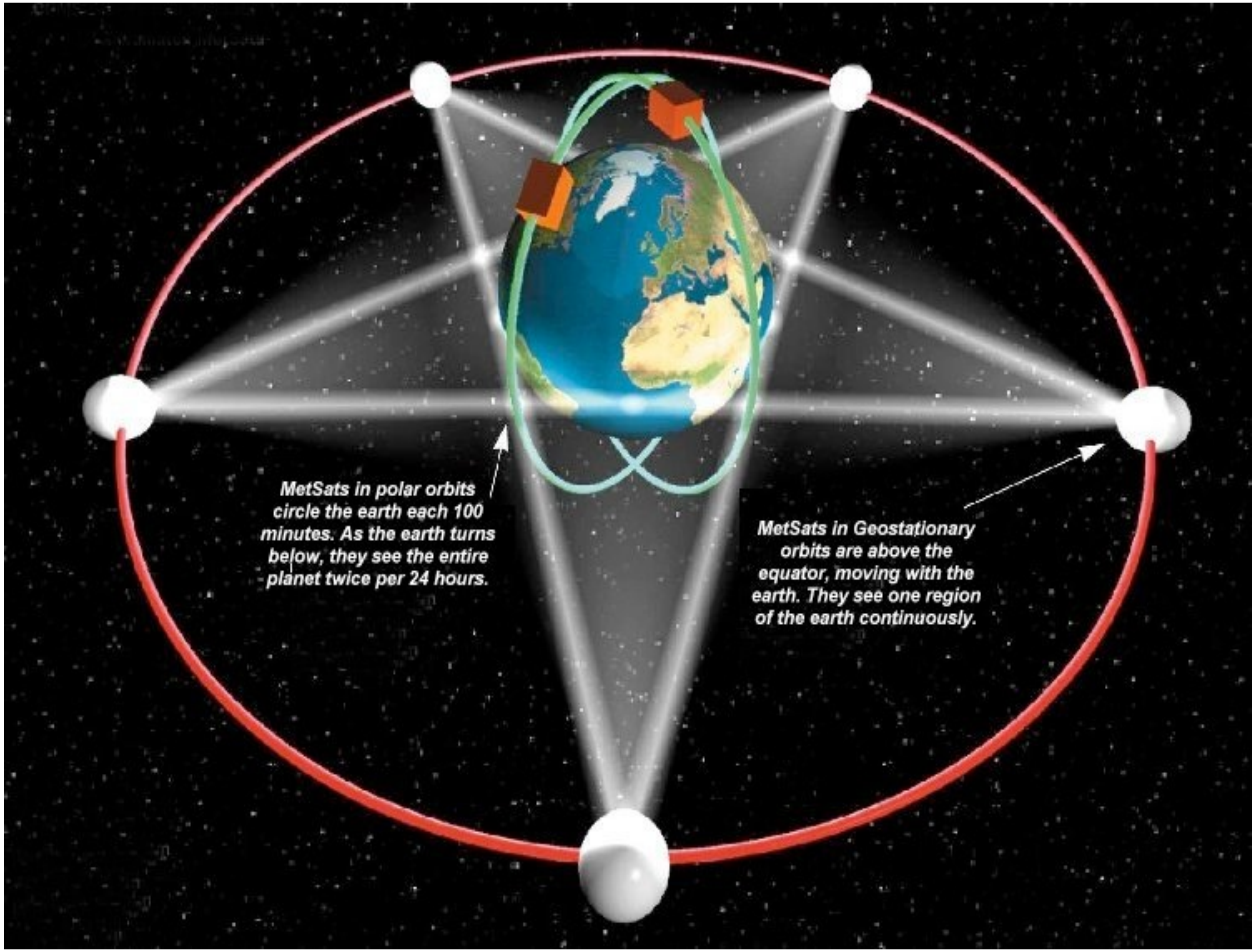
Remote Sensing Basics

Orbit Types

Geostationary and Polar Orbiting Satellites

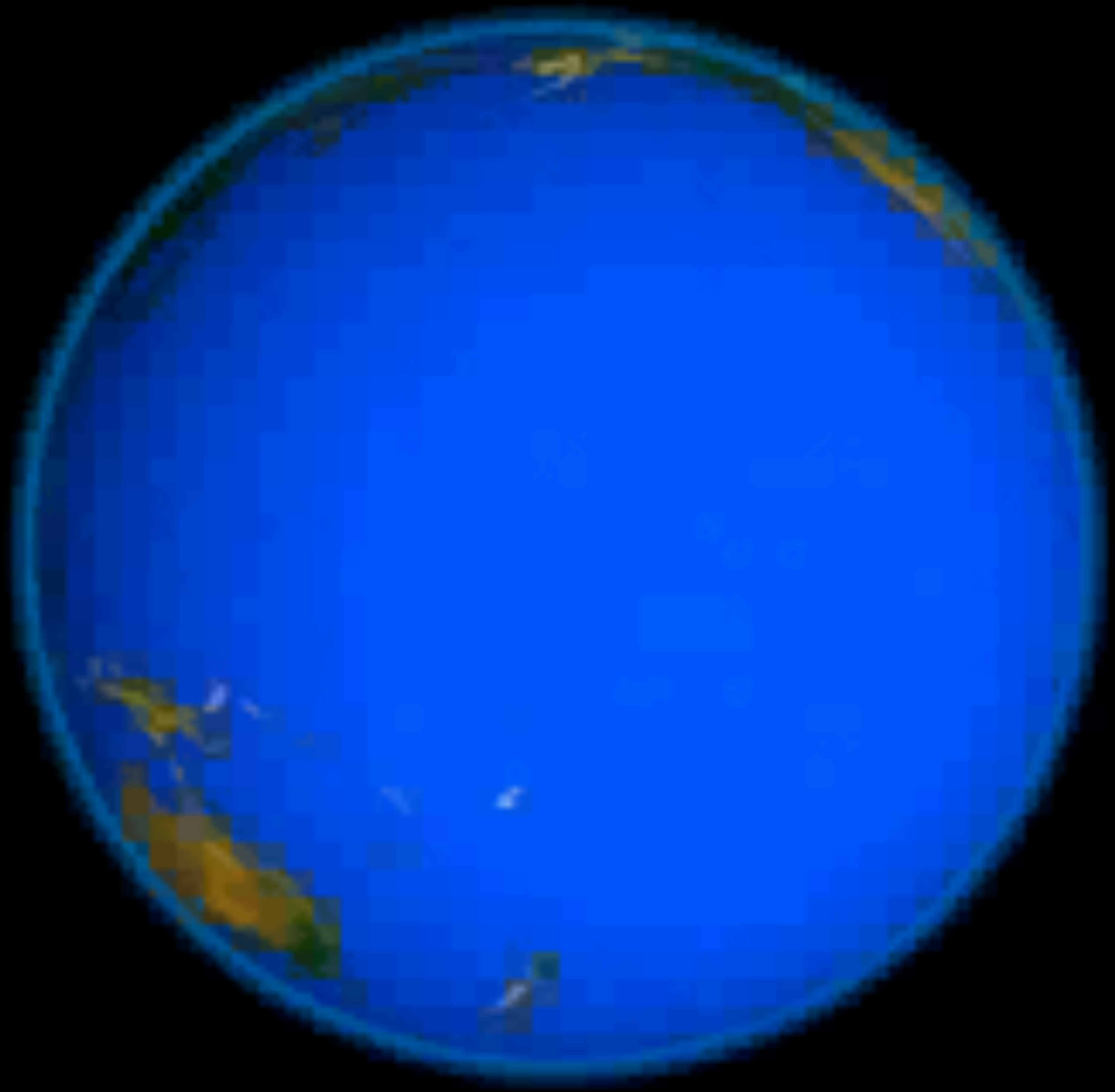
1. A single **polar orbiting** satellite can view the entire earth once a day

2. A single **geostationary** satellite can view a limited region of the earth, but can do so continuously throughout the day



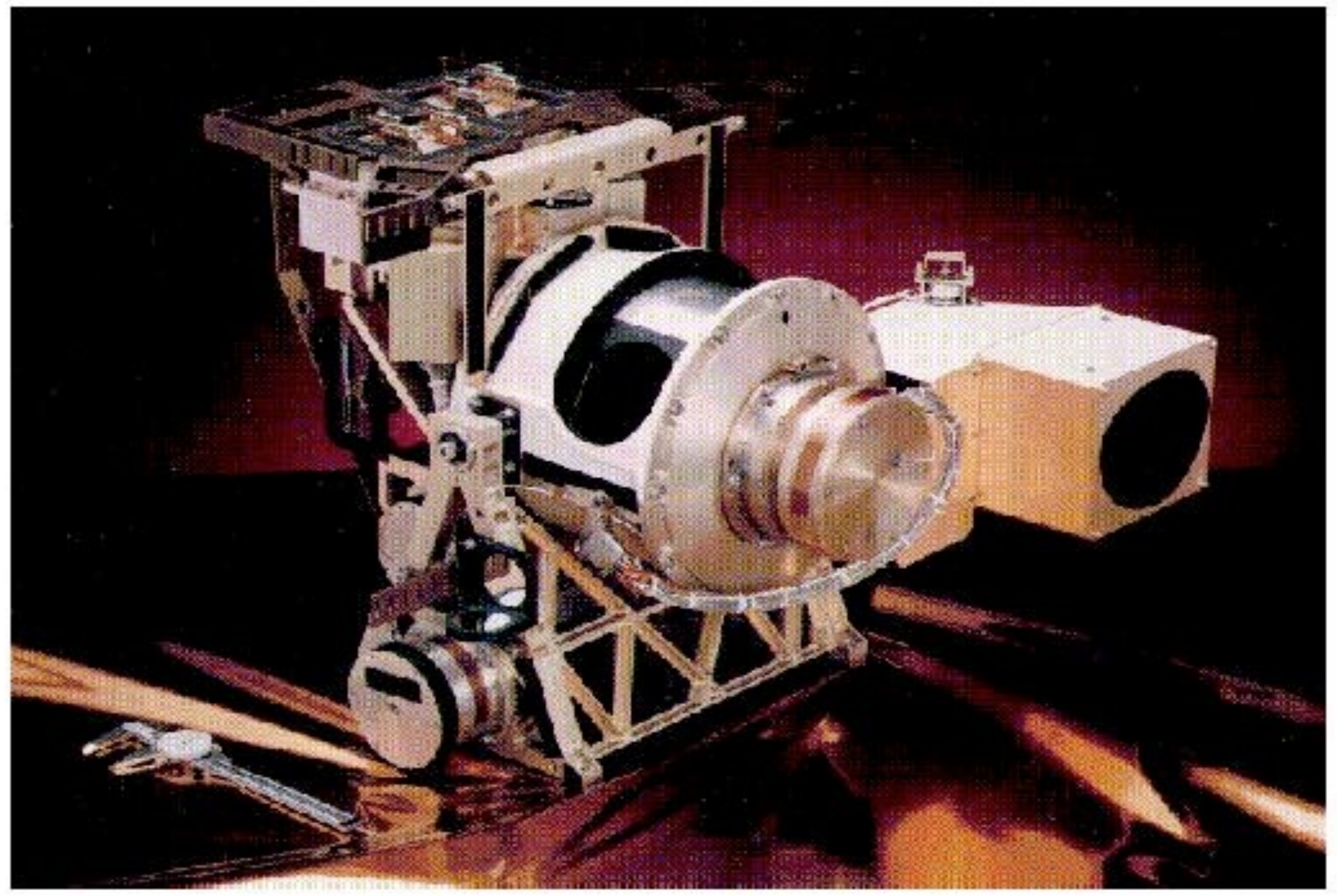
Note that a geostationary satellite orbits the earth at the same rate that the earth rotates and in effect, remains exactly above a fixed point on the earth

Polar Orbiting Satellite



SeaWiFS

(**Sea-**viewing **Wi**de **F**ield-of-view **S**ensor)

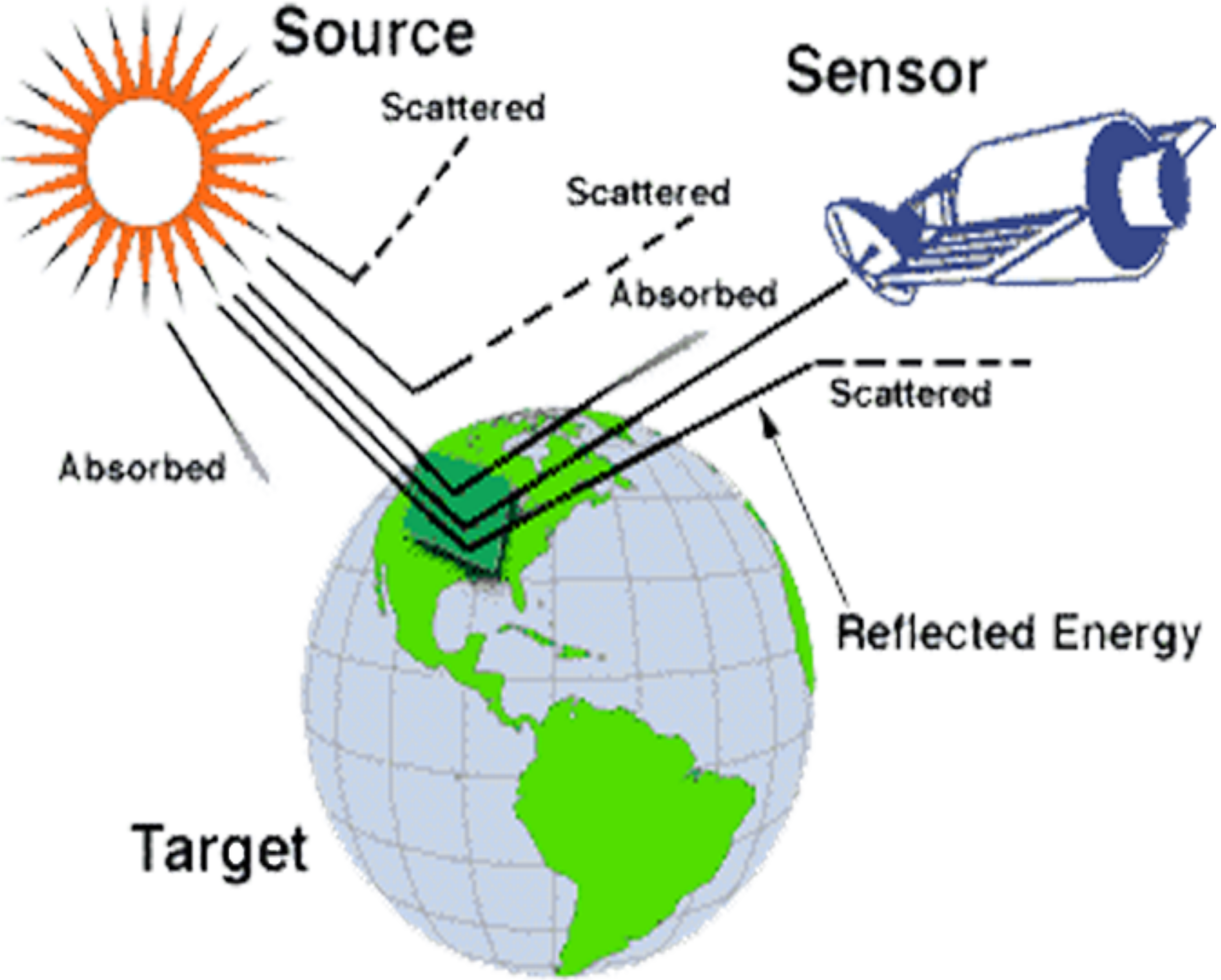


Sensor Types (active and passive)

1. **Passive Sensors** measure electromagnetic radiation that has a natural origin
    - Solar radiation **reflected** or scattered from a surface
    - Thermal radiation **emitted** from a surface
2. **Active Sensors** measure electromagnetic radiation that is **generated by the satellite**, sent down to the surface and then reflected or scattered back to the satellite

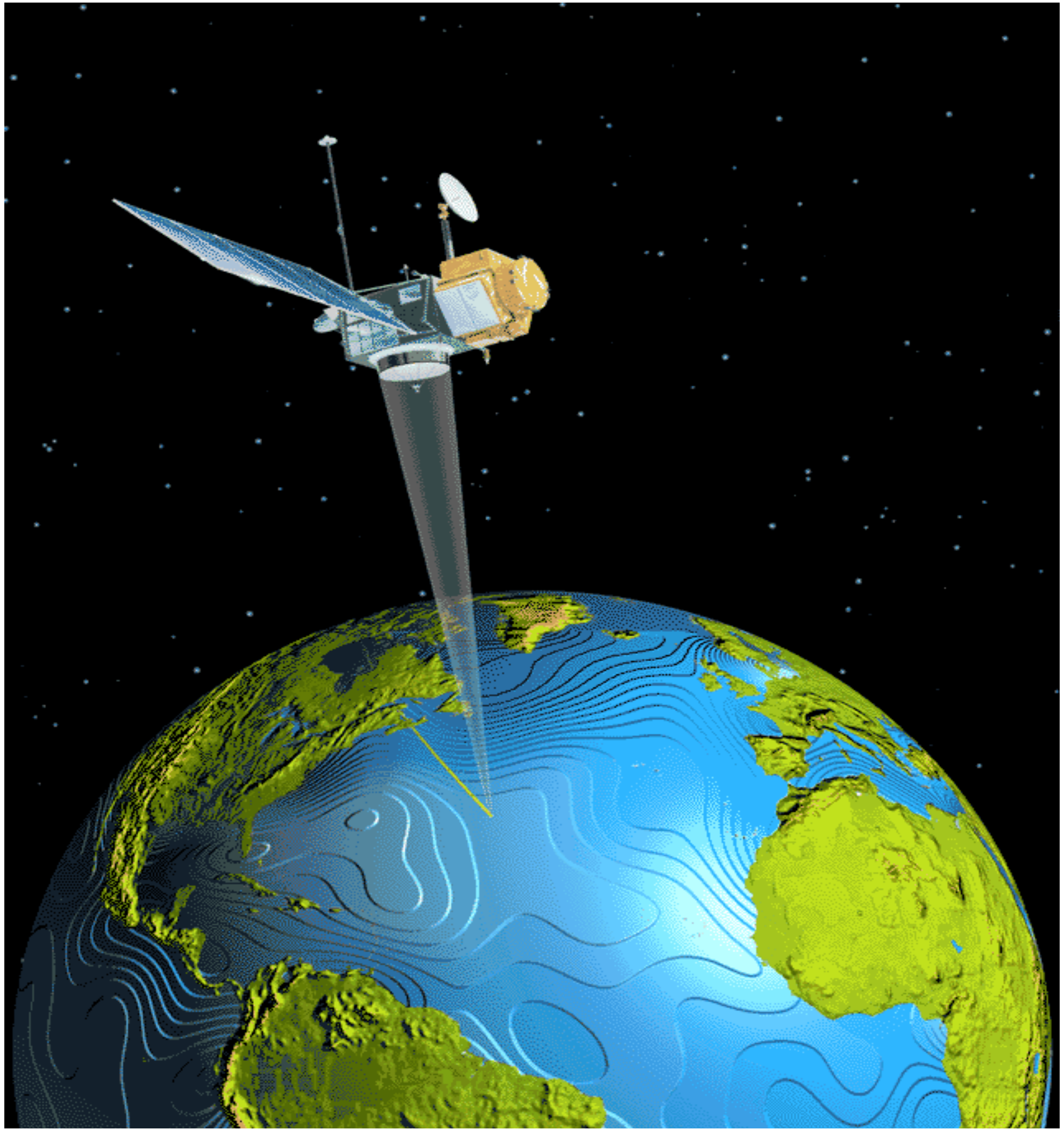
Diagram of a Passive Satellite Sensor

Uses electromagnetic signals from the sun that are scattered of reflected off the earth's surface or are emitted from the earth surface



Example of an Active Satellite Sensor

Topex-Poseidon Altimeter is an example of an active satellite sensor (i.e., is uses its own source of electromagnetic radiation

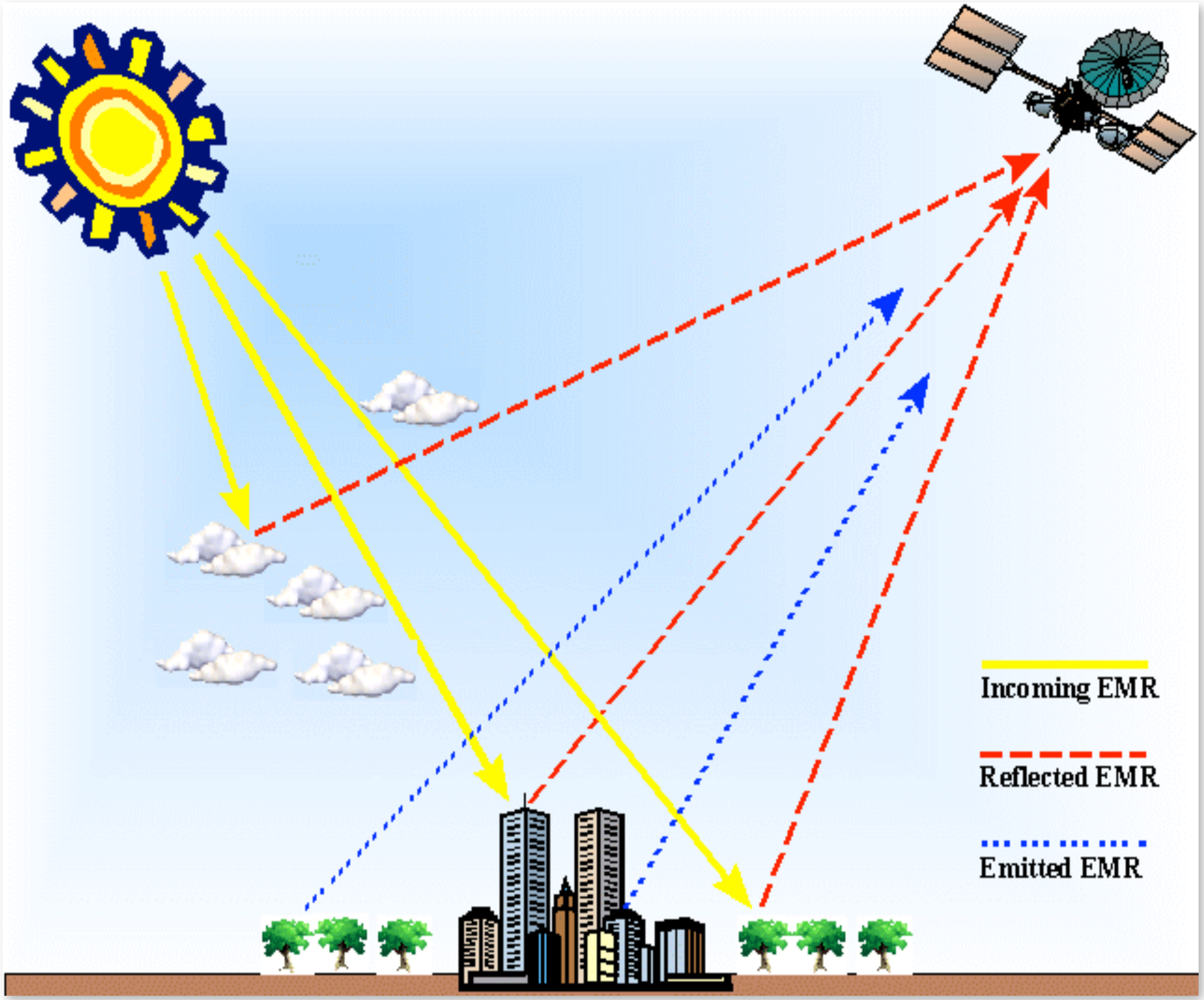


Reflected Radiation

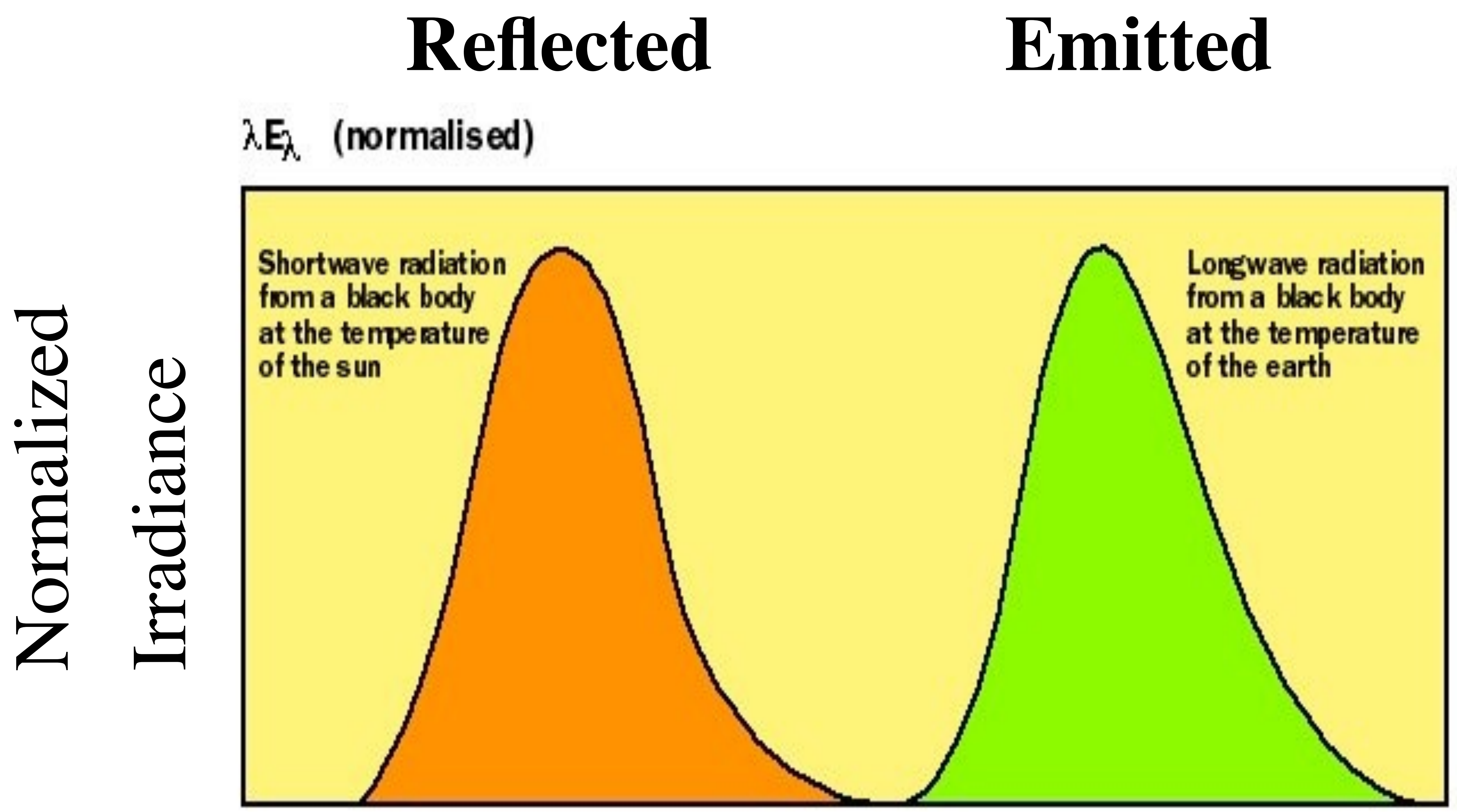
Short Wavelength

Emitted Radiation

Long Wavelength



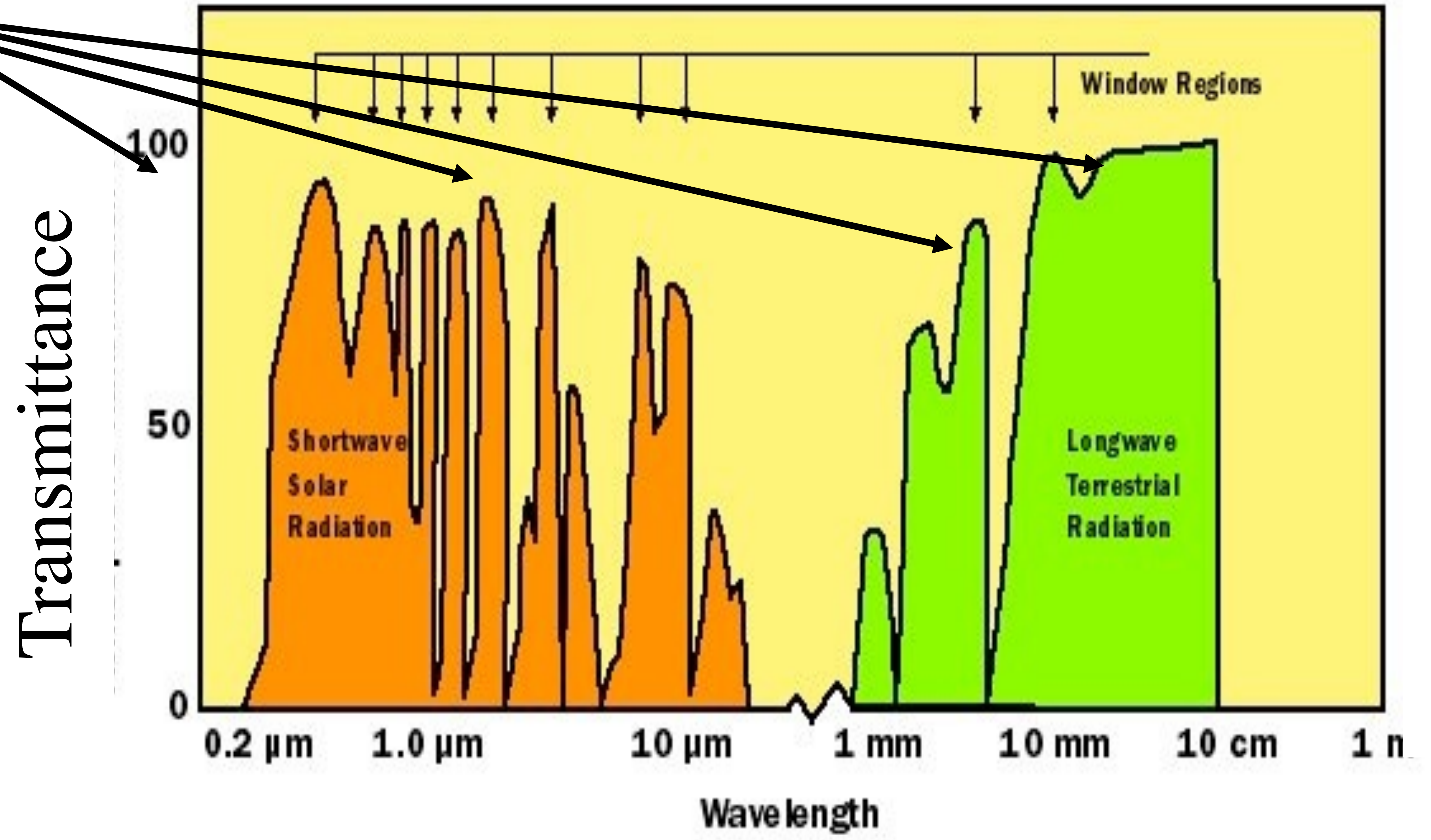
Most solar energy comes to the earth as **short wavelength** electromagnetic radiation (visible light) and a portion of this radiation is absorbed and then re-radiated (emitted) back to space as **long wavelength** electromagnetic radiation



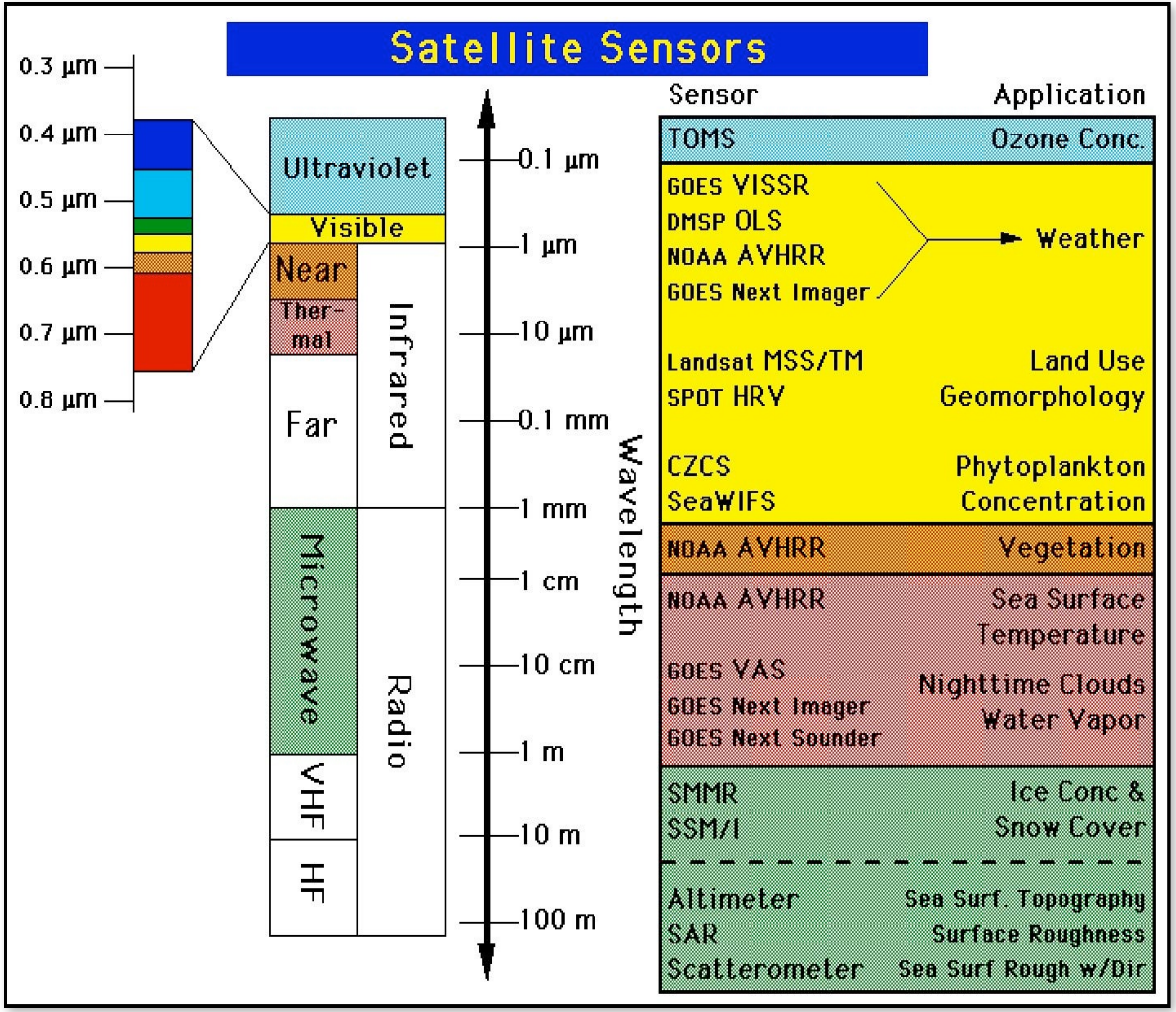
1. There are discrete **atmospheric windows** through which electromagnetic radiation can be transmitted

2. High transmittance windows used to view the earth's surface

3. Low transmittance regions used for vertical sounding of the atmosphere



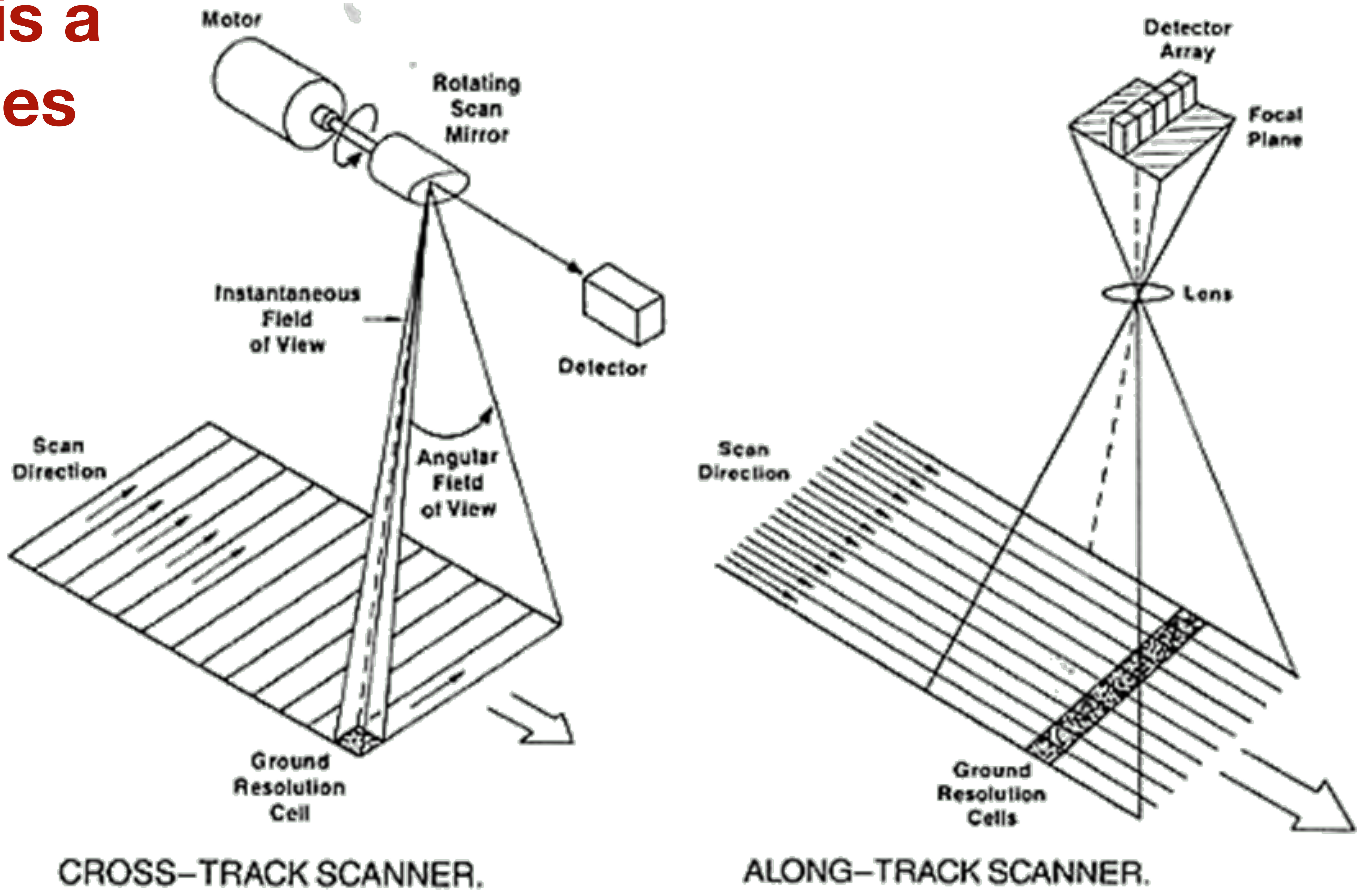
A common feature of all satellites is that they only measure electromagnetic radiation. The geophysical parameter to be measured dictates what wavelengths need to be measured



Digital Imagery

Cross-Track and Along-Track Scanners

In both cases, the result is a 2D array of radiance values

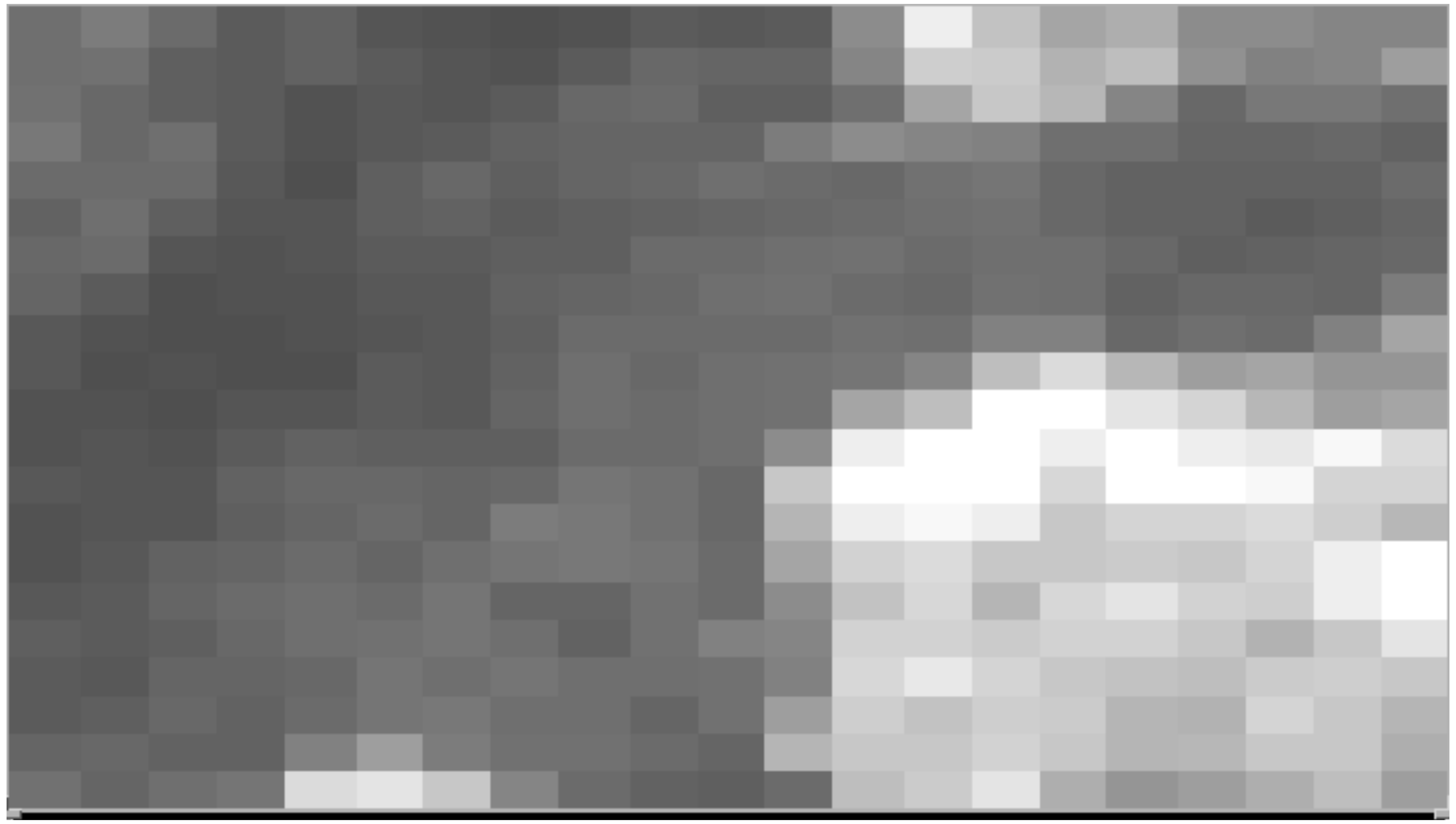


1. Satellite sensors measure the intensity of electromagnetic radiation (EM), **for specified wavelengths,** at the top of the atmosphere for **narrowly-defined patches (solid angles / pixels)** via a telescope that focuses the EM radiation onto a series of light detectors (**radiometers**).

2. The configuration of the light detectors and telescope varies between sensor types but, in the end, all sensors produce a set of equally spaced boxes/pixels (**i.e., a 2-D array of measured EM values**) where each individual array element (pixel) contains the value of the intensity of EM radiation (watts m^{-2}) for a specific wavelength from each narrowly defined-location on earth.

3. **The resulting 2-D array can be displayed as an image or it can be analyzed as a 2-D array of numbers.**

4. The size of the rectangular region on earth over which the instrument averages the EM radiation onto a single light detector is referred to as **the instrument resolution.** For example, 1-km resolution sensor averages EM intensity over a 1-km by 1-km region on the earth (at nadir).



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111	124	107	91	98	85	82	79	82	91	88	91	142	238	194	168	171	142	142	136	136
111	113	95	91	98	91	85	82	91	104	101	101	136	206	203	178	187	145	127	136	161
113	104	95	91	82	88	85	91	104	107	95	95	111	165	199	183	133	104	120	120	111
120	104	111	91	82	88	91	98	101	101	101	124	140	136	129	111	111	101	101	104	98
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101	91	79	82	82	88	88	98	101	104	111	113	107	104	113	111	98	104	104	101	124
88	82	79	79	82	85	88	95	107	107	107	107	113	111	127	127	104	111	107	129	165
88	79	82	79	79	91	88	98	111	104	111	113	117	133	187	219	183	161	165	152	149
82	82	79	85	85	91	88	101	111	107	111	113	168	190	255	255	228	212	183	161	168
82	85	82	91	98	95	95	95	107	107	111	142	241	255	255	235	255	238	232	248	219
88	85	85	98	104	104	101	104	117	113	104	197	255	255	255	215	255	255	251	212	212
82	85	85	95	101	107	101	124	120	113	104	181	241	251	235	199	212	212	219	206	183
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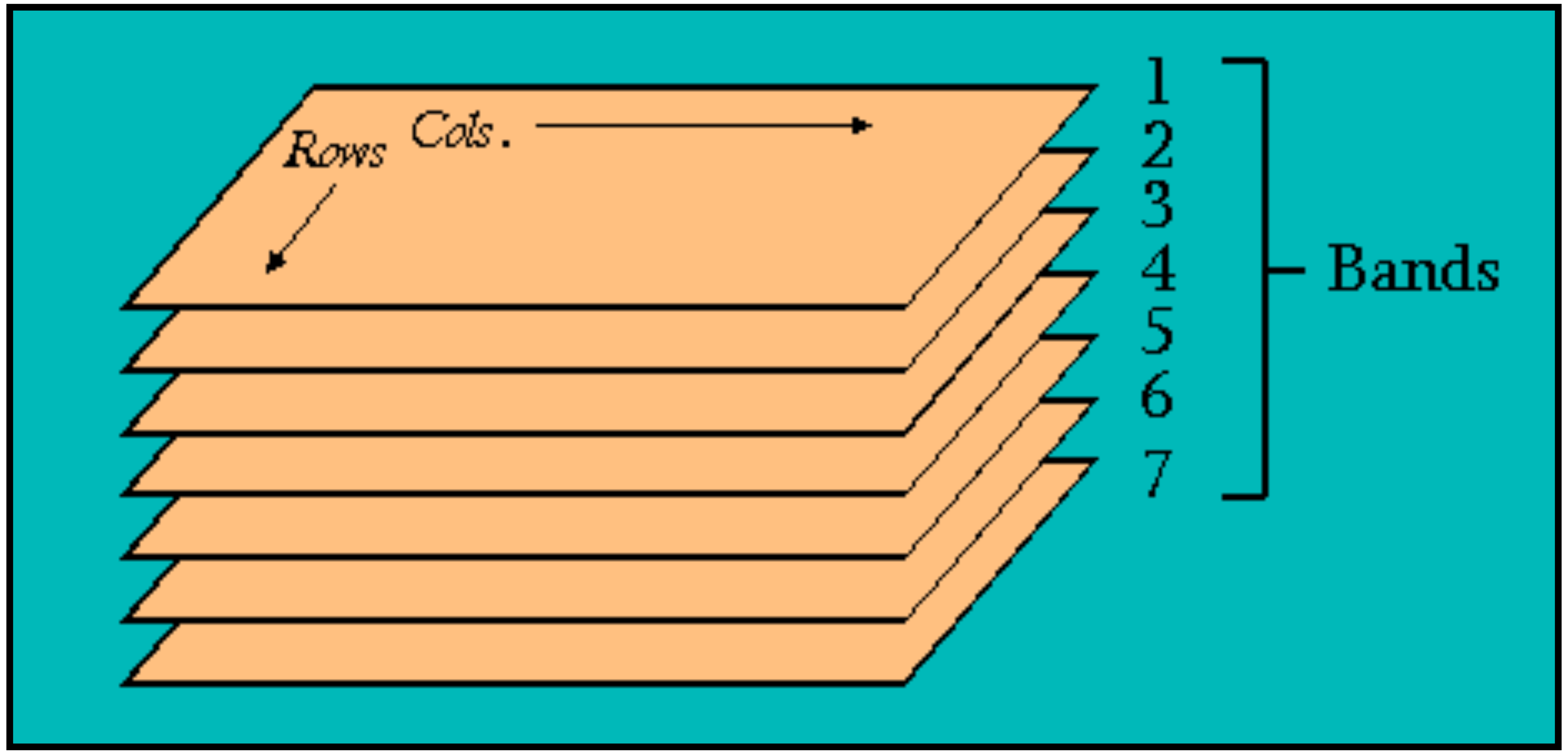
88	91	101	107	111	107	117	101	101	113	107	140	194	215	181	215	226	210	206	241	255
95	91	95	104	111	113	117	111	98	113	129	133	210	210	203	210	210	199	178	199	228
91	88	101	101	104	117	111	117	111	111	113	127	215	232	212	199	194	187	203	206	199
91	95	104	98	107	117	120	111	111	101	113	158	206	194	206	203	181	178	212	199	181
101	104	98	98	129	161	124	113	113	107	101	181	199	197	210	199	181	183	199	199	174
113	101	111	117	219	228	197	133	107	98	95	107	187	203	228	171	149	161	174	190	161

1. **Multispectral satellite imaging radiometers** measure EM radiation intensity centered on **a few specified wavelengths**
2. Each wavelength is defined by a **central wavelength** and a small range of wavelengths about each central wavelength called a **bandwidth.**
3. The intensity of EM radiation at each wavelength is stored separately in a stack of digital images (2-D matrices) corresponding to the EM radiation intensity for each respective wavelength/bandwidth.

- Each separate image is called a wavelength **band** or a wavelength **channel**.
- Each band or channel can be referred to by its central wavelength value or by sequential band numbering (1, 2, 3, …).



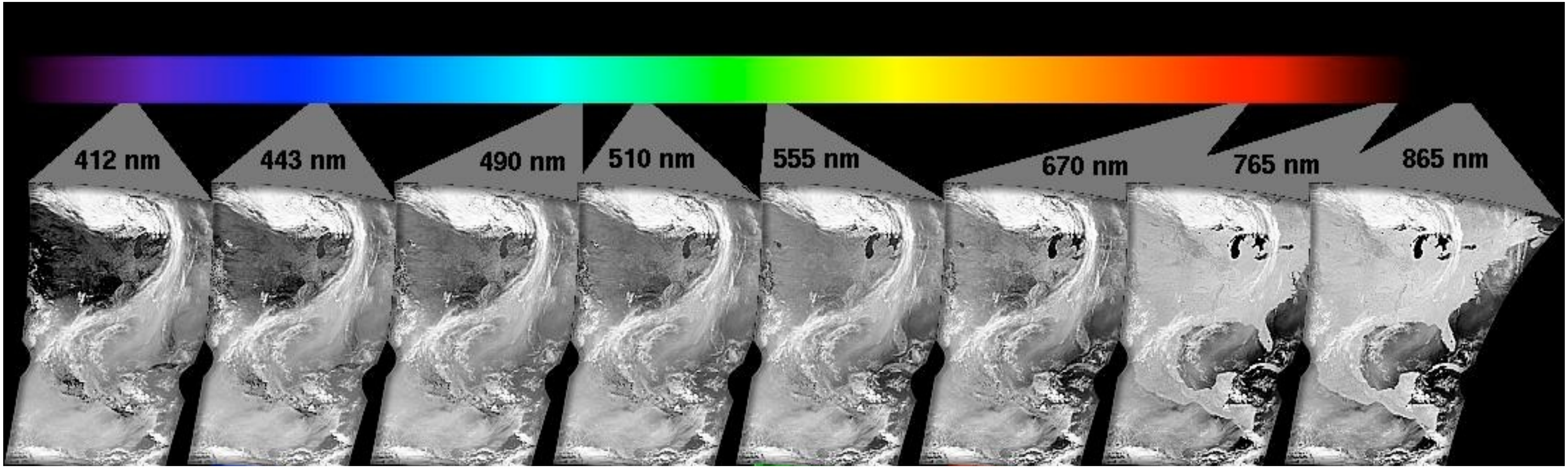
Higher Order Data Products

Generated from a creative mathematical combination of the EM radiances for various sensor bands

Example of Using Band Combinations to Make Higher Order Products

- In this case making a true color image from the addition of separate Red, Green and Blue bands.

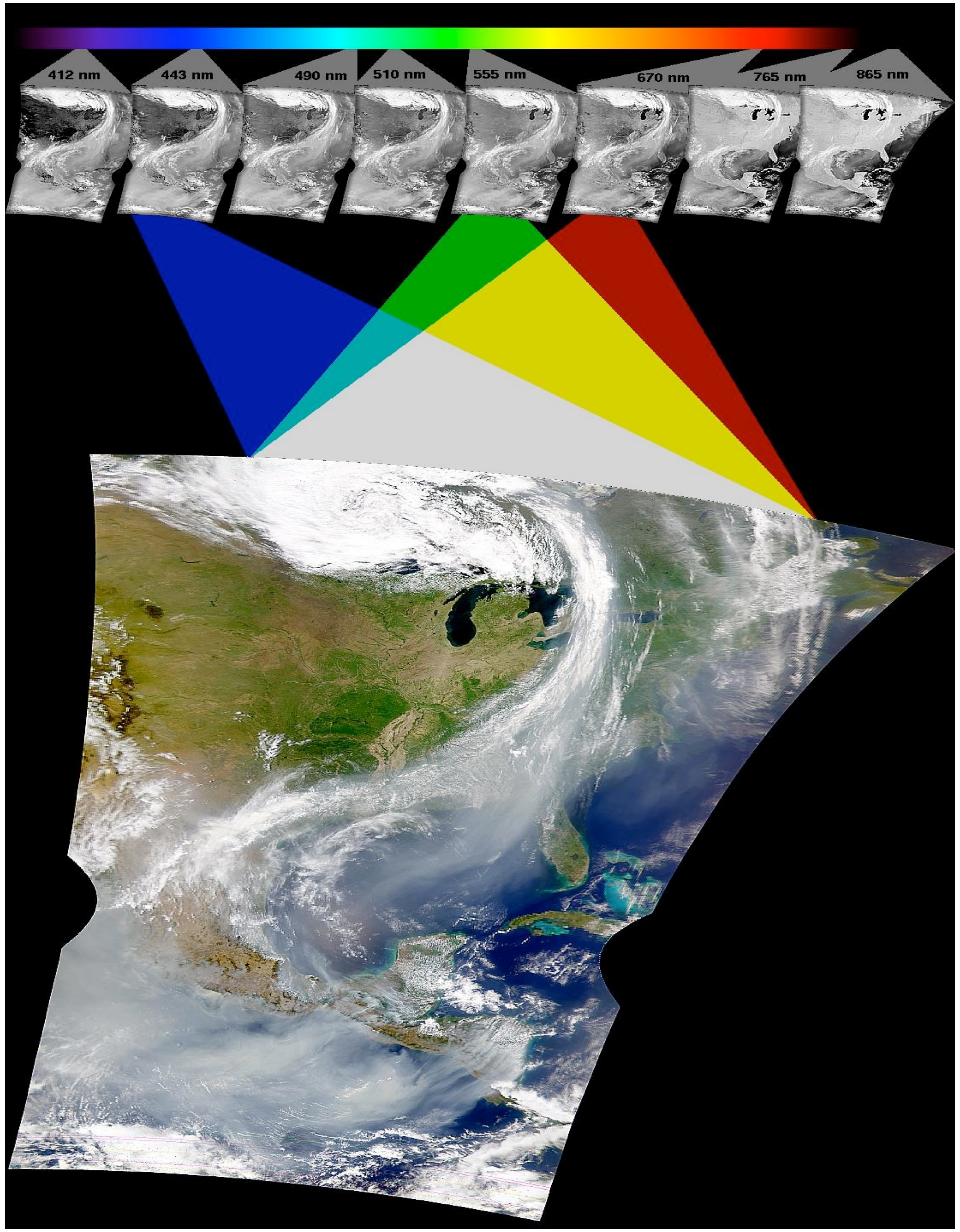
Intensity of the 8 Visible and Near-Infrared Bands from the SeaWiFS Sensor for East Coast of the United States



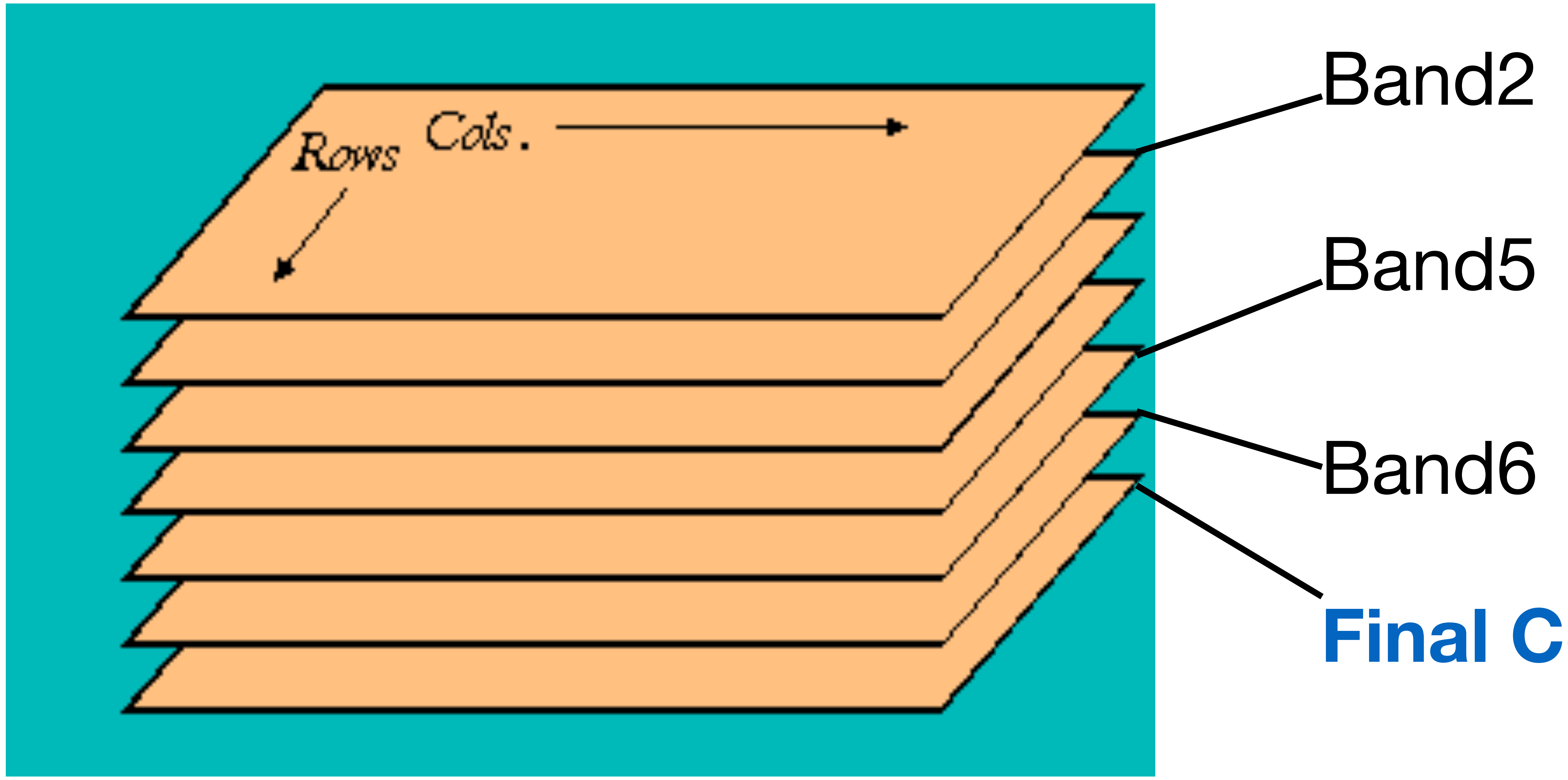
True-Color Image

Created from bands 2, 5, and 6 with corresponding wavelengths of 443, 555 and 670 nm (+/-10 nm)

Final Color Image = C_1*band2 + C_2*band5 + C_3*band6

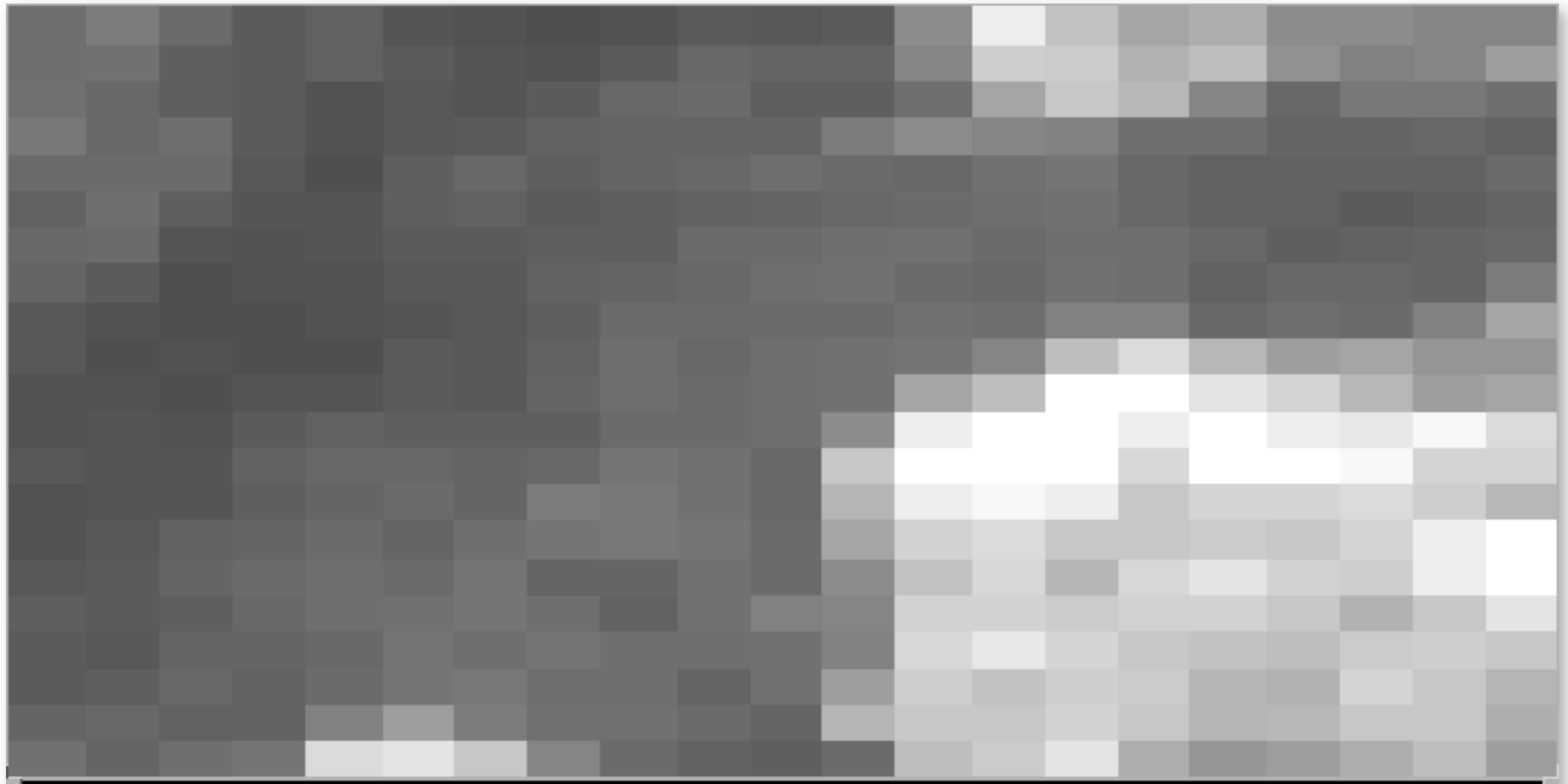


The New Image Product is Often Appended to the Original File Containing all of the EM Radiance Bands



Note: In this example a True Color Image was computed from three EM Radiance Bands, but in the future it will be shown that other geophysical products can be computed in an analogous manner (e.g., Chlorophyll, SST, Wind Speed, etc…).

Equivalence of a gray-scale image and its corresponding numerical value



111	124	107	91	98	85	82	79	82	91	88	91	142	238	194	168	171	142	142	136	136
111	113	95	91	98	91	85	82	91	104	101	101	136	206	203	178	187	145	127	136	161
113	104	95	91	82	88	85	91	104	107	95	95	111	165	199	183	133	104	120	120	111
120	104	111	91	82	88	91	98	101	101	101	124	140	136	129	111	111	101	101	104	98
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88	79	82	79	79	91	88	98	111	104	111	113	117	133	187	219	183	161	165	152	149
82	82	79	85	85	91	88	101	111	107	111	113	168	190	255	255	228	212	183	161	168
82	85	82	91	98	95	95	95	107	107	111	142	241	255	255	235	255	238	232	248	219
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82	85	85	95	101	107	101	124	120	113	104	181	241	251	235	199	212	212	219	206	183
82	88	98	101	107	101	111	117	120	117	107	165	210	219	199	199	203	199	212	241	255
88	91	101	107	111	107	117	101	101	113	107	140	194	215	181	215	226	210	206	241	255
95	91	95	104	111	113	117	111	98	113	129	133	210	210	203	210	210	199	178	199	228
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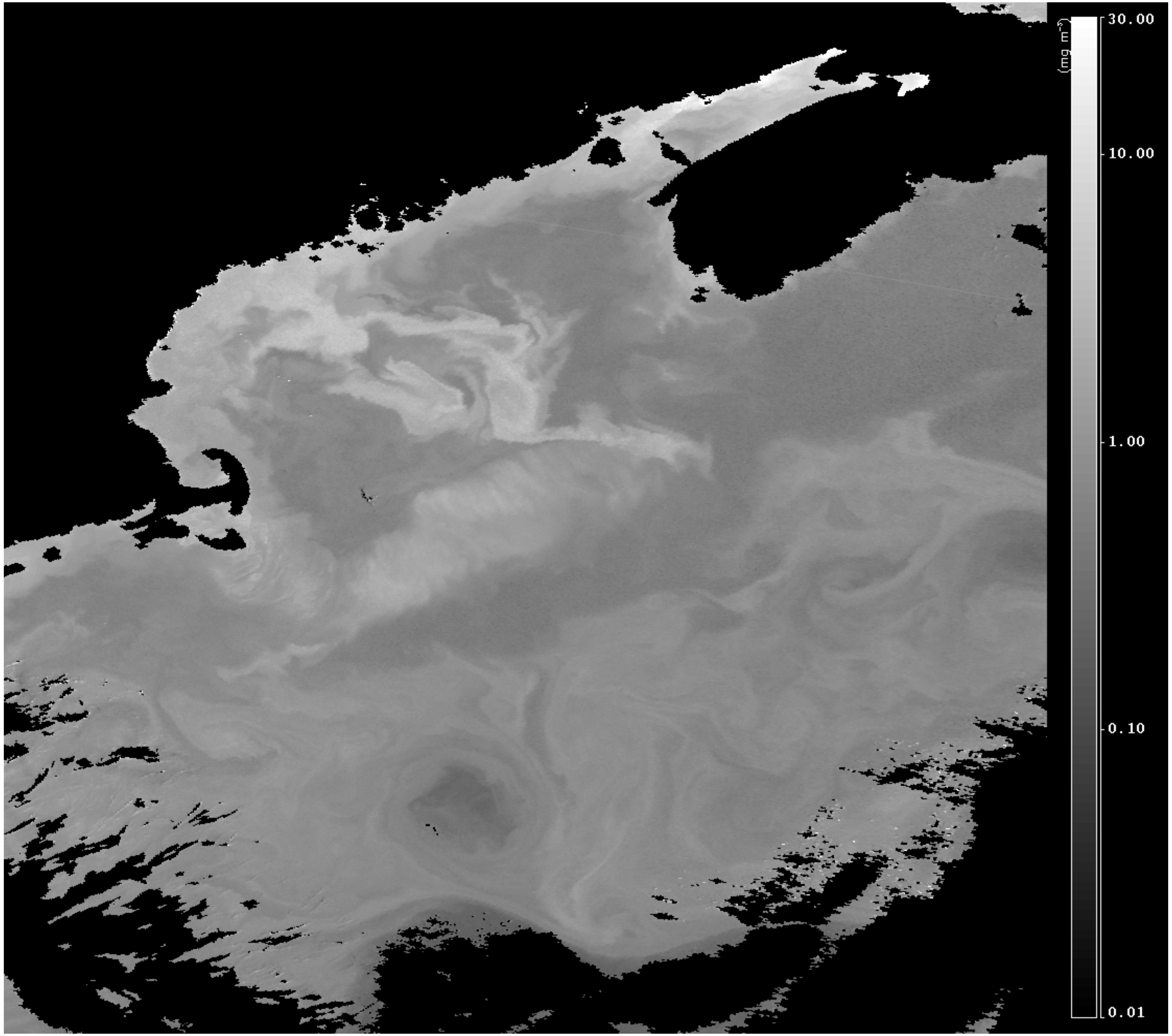
101	104	98	98	129	161	124	113	113	107	101	181	199	197	210	199	181	183	199	199	174
113	101	111	117	219	228	197	133	107	98	95	107	187	203	228	171	149	161	174	190	161

If you calculate a single geophysical parameter such as chlorophyll concentration or sst, you can apply a gray scale or you can use color coding for the geophysical value at the pixel location.



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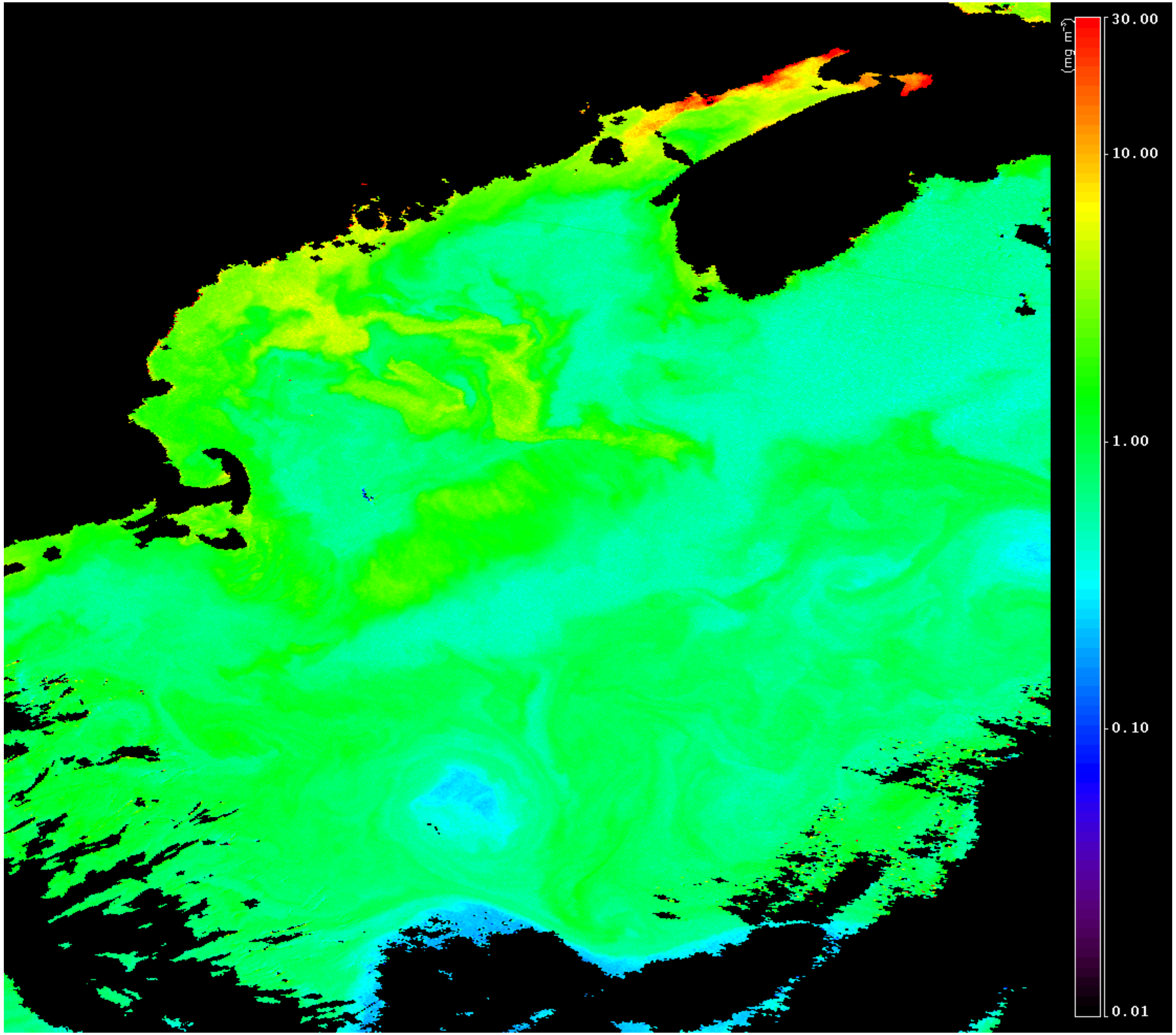

Summary I

1. Orbits
   Geostationary and Polar Orbiting
2. Sensors
   Passive and Active
3. Radiation
   Reflected (short wavelength) and Emitted (long wavelength)
4. Atmospheric Windows
   High transmittance good for seeing earth surface
   Low transmittance good for vertical sounding of the atmosphere

Summary II

1. Satellite data is composed of separate bands
    - each band depicts respectively, an image of the radiant intensity at narrowly defined wavelengths
2. A single band can be presented as a:
    - **grey-scale or color image** where the grey-scale (color scale) is indexed to a given numerical value of radiant intensity level. The color bar is used to decode grey/color scale to numerical values
    - **matrix of numbers** specifying the radiance level at each pixel location
3. Bands can be combined mathematically to create higher-order data products
    - e.g., true color images or geophysical products (e.g., chlorophyll or SST).