

**Remote Sensing Instruments**

Material from “Remote Sensing Instrumentation” in *Weather Satellites: Systems, Data, and Environmental Applications* by Rao, Holmes, Anderson, Winston, and Lehr, 1990.

***OUTLINE***

I. Sensor classification

- A. active vs. passive
- B. imaging vs. non-imaging vs. sounding
- C. wavelength sensitivity
- D. scanning vs. non-scanning

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- A. visible and near-infrared
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- C. microwave
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- V. Examples: TOVS (TIROS Operational Vertical Sounder)  
CERES (Clouds and the Earth’s Radiant Energy System)

*Key terms and concepts:*

FOV vs. IFOV      nadir      zenith      spatial resolution      spectral resolution  
temporal resolution      signal/noise ratio      swath      multispectral scanner

*good URLs:*

[www.ccrs.nrcan.gc.ca/ccrs/eduref/ref/glosndxe.html](http://www.ccrs.nrcan.gc.ca/ccrs/eduref/ref/glosndxe.html) -- remote sensing glossary

[ls7pm3.gsfc.nasa.gov](http://ls7pm3.gsfc.nasa.gov) -- LandSat

[asd-www.larc.nasa.gov/ceres/ASDceres.html](http://asd-www.larc.nasa.gov/ceres/ASDceres.html) -- CERES

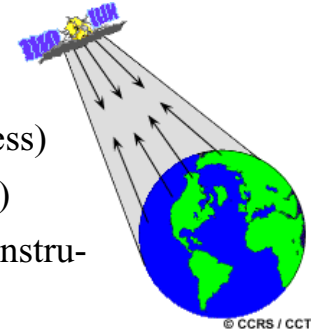
[www.jhbunn.co.uk/galaxy/RSLinks.html#Teach](http://www.jhbunn.co.uk/galaxy/RSLinks.html#Teach) -- pedagogical remote sensing sites

## I. Sensor Classification

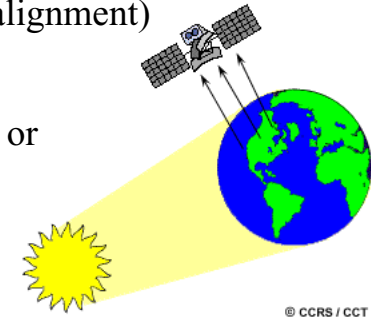
### A. Active versus passive

Active -- instrument sends signal and measures energy reflected back

- => intensity of reflected signal related to properties of target (e.g., density, thickness)
- => time until return used to calculate distance away (e.g., height of surface, shape)
- => doppler shift of reflected signal reveals motion of target toward or away from instrument
- => polarization of reflected signal related to composition (e.g., phase, crystal alignment)

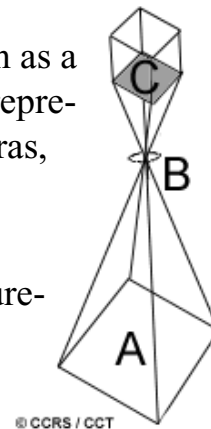


Passive -- instrument measures energy emitted from an object (e.g., infrared or microwave) or amount of solar radiation reflected by surfaces and objects (e.g., AVHRR, TOVS, SSM/I, SSMR, MODIS, CERES, LandSat)



### B. Imaging versus non-imaging versus sounding

- => Imaging -- system that measures radiation as a function of position so a 2-D graphical representation can be constructed (e.g., cameras, scanners)
- => Non-imaging -- point measurement (e.g., acoustic or seismic data) or a line measurement (e.g., moving laser)
- => Sounding -- produces vertical profile (e.g., temperature, moisture, ozone)

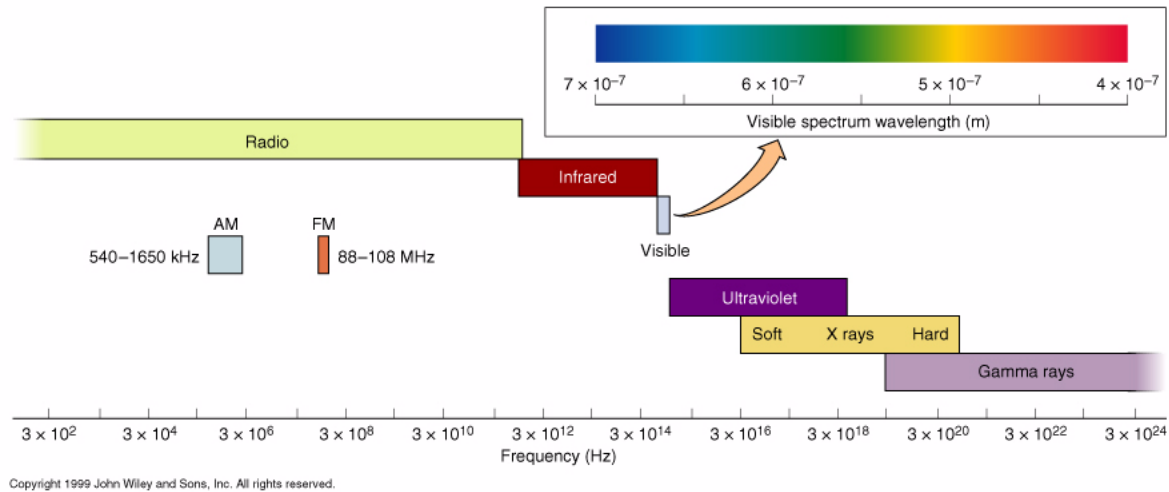


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170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

C. Wavelength sensitivity -- portion of EM spectrum to which instrument is sensitive. E.g., visible, UV, IR, microwave, interferometer. Signal/noise ratio is an issue in some wavelengths with weak emission.

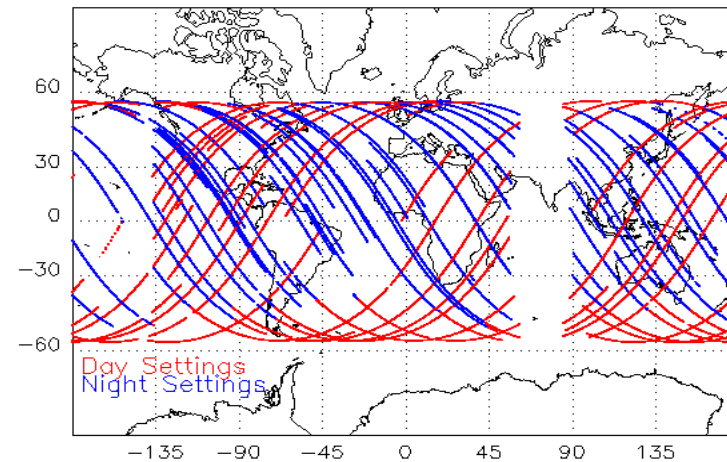


#### D. Scanning versus non-scanning

- => Scanners -- sensor with narrow IFOV that sweeps (either mechanically or electronically) over terrain to produce image
- => Non-scanner -- either IFOV doesn't sweep (e.g., laser) or image is created instantaneously (e.g., photography)

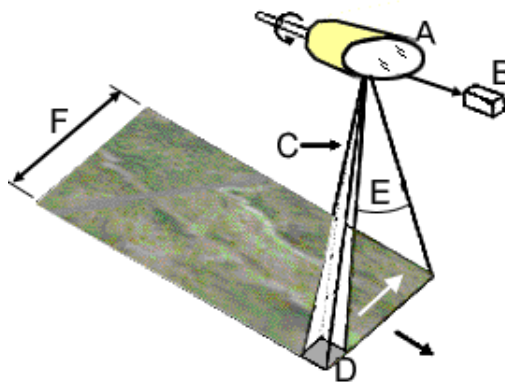
#### LITE Orbit path

#### Lidar In-Space Technology Project



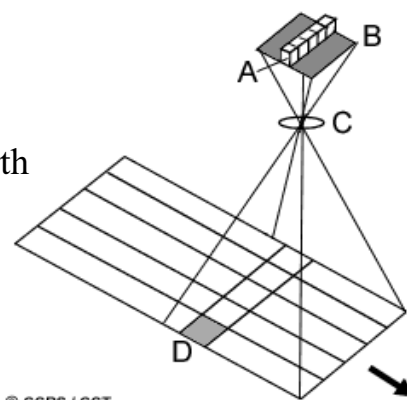
## II. Image generation by scanners

A. Whisk-broom (across track) -- rotating mirror moves IFOV perpendicular to sensor motion. View angle changes. (e.g., AVHRR, LandSat)



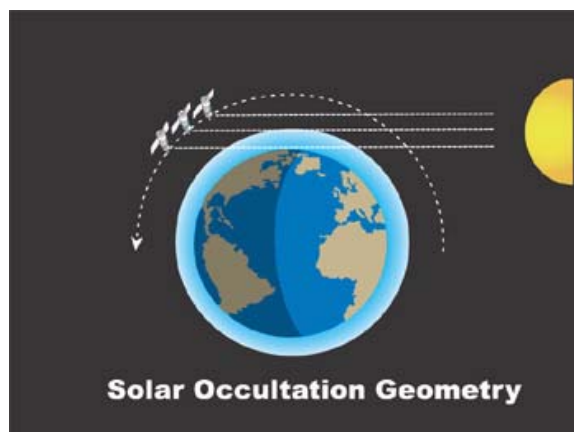
B. Conical scanners -- similar to whisk broom but mirror is inclined so view angle remains constant (e.g., OLS, SSM/I)

C. Push-broom (along-track) -- linear array of detectors that moves across Earth because of sensor's motion

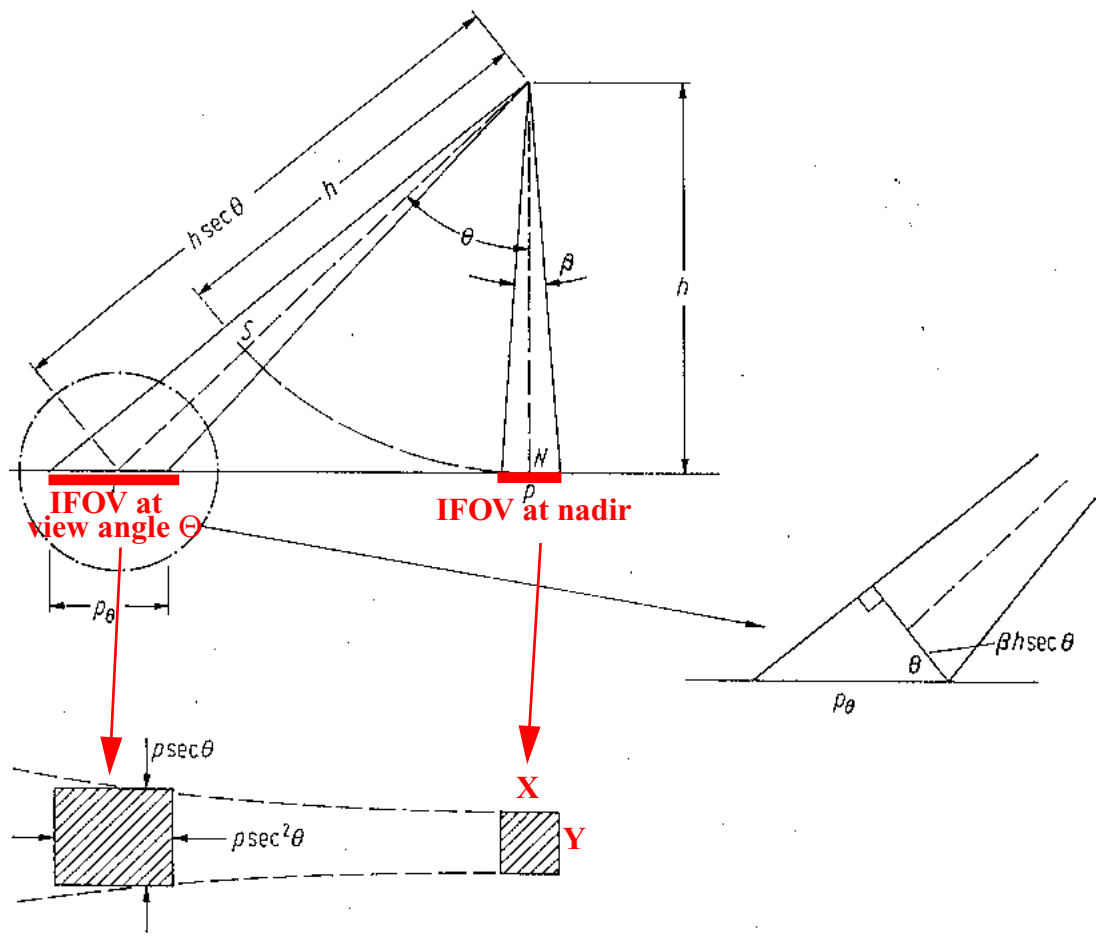


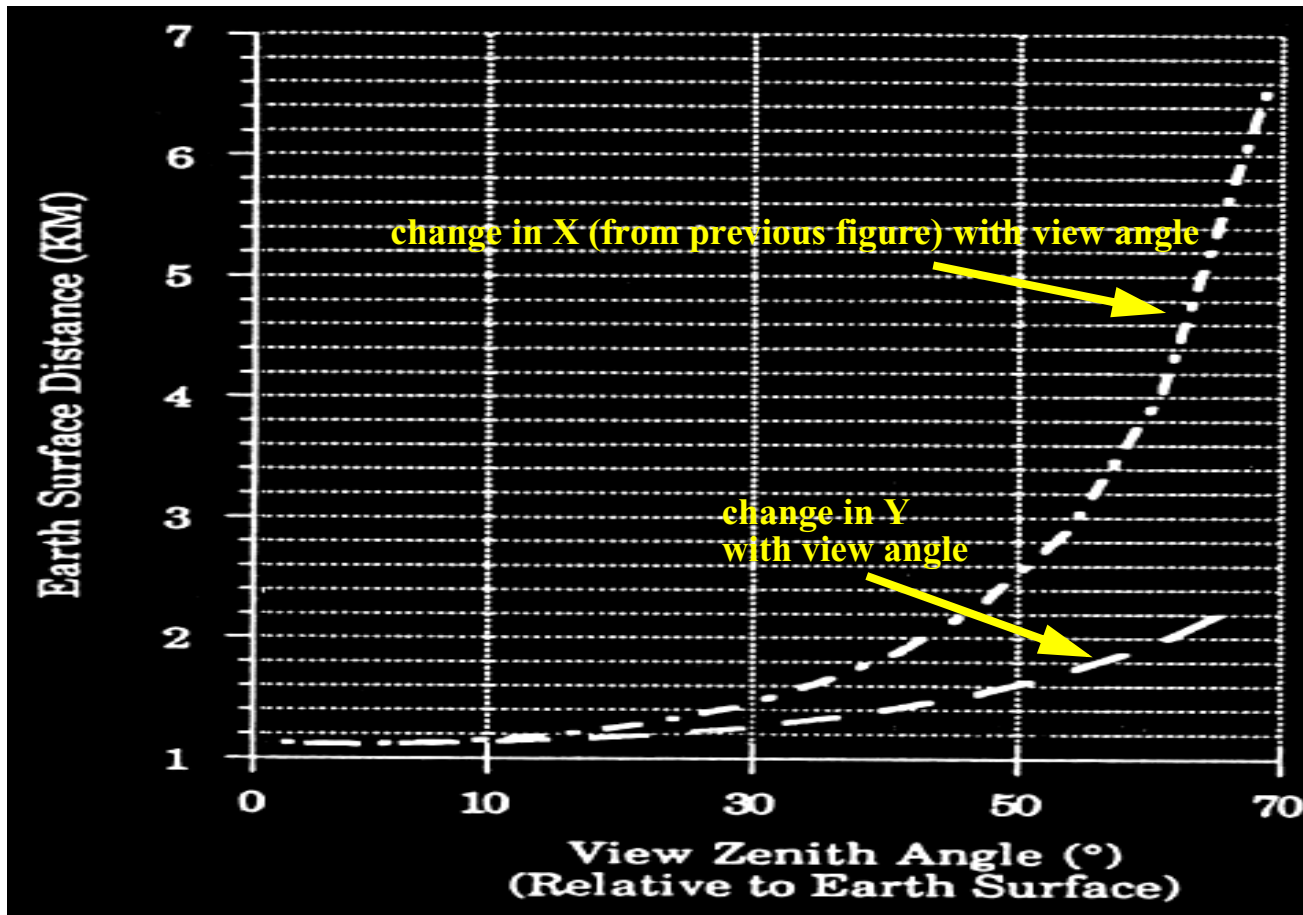
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D. Limb scanner -- views tangent of atmosphere so scan produces vertical profile



E. Scan angle effects -- IFOV gets larger with view angle. IFOV is proportional to view angle.





### III. Detector types

- A. Visible and NearIR -- usually photodiodes or photo-multipliers. Incident photon accelerated toward sensor using photoelectric effect. Amplifies energy so weak signals measurable.
- B. Infrared -- 2 types
  1. Thermal responding -- energy from object caused temperature change in a special material => change in resistance (bolometer), voltage (thermopile), or current (pyroelectric device).
  2. Photo-responding -- change in the number of photons hitting sensor => change in voltage or resistance. Advantages: faster, spectrally selective, sensitive to small changes. Disadvantage: complex
- C. Microwave -- change in intensity => conductor => fluctuating current => amplifier. Long wavelength => resolution limited => need antenna
- D. Interferometers -- use interference patterns generated by two energy beams => differentiate small wavelength differences

### IV. Calibration -- methods to check absolute accuracy

#### A. Internal versus external

Internal -- a body inside instrument with carefully controlled temperature that is occasionally viewed by sensor

External -- same as above, but sensor views external standard source, e.g., deep space (cold), moon, sun

#### B. Earth targets -- sensor views homogeneous regions with known characteristics, e.g., desert, ocean, ice sheets

### V. Terms to know

1. IFOV vs. FOV -- IFOV is the field of scanner with no instrument motion or scanning. Units: solid angle or area. FOV is the area or solid angle viewed by a moving and/or scanning sensor. Motion of sensor results in  $IFOV < FOV$ .
2. Signal/noise ratio -- measured energy divided by random variability in sensor output. Large values desired.
3. Spatial resolution -- distance between 2 points discernible by sensor.

4. Temporal resolution -- time interval between 2 observations.
5. Spectral resolution -- interval between two wavelengths discernible by sensor
6. Swath -- pattern of scans on Earth's surface
7. Multispectral scanner -- array of sensors that measure several spectral bands of EM energy simultaneously.
8. Nadir -- view straight down
9. Zenith -- view straight up

## VI. Examples

### Swath from CERES in normal scanning mode

