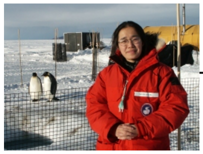


Lecture 02. Overview of Remote Sensing

- Concept and Picture of Remote Sensing
- Content of Remote Sensing
- Classification of Remote Sensing
- Passive Remote Sensing
- Active Remote Sensing
- Comparison of Remote Sensing
- Summary

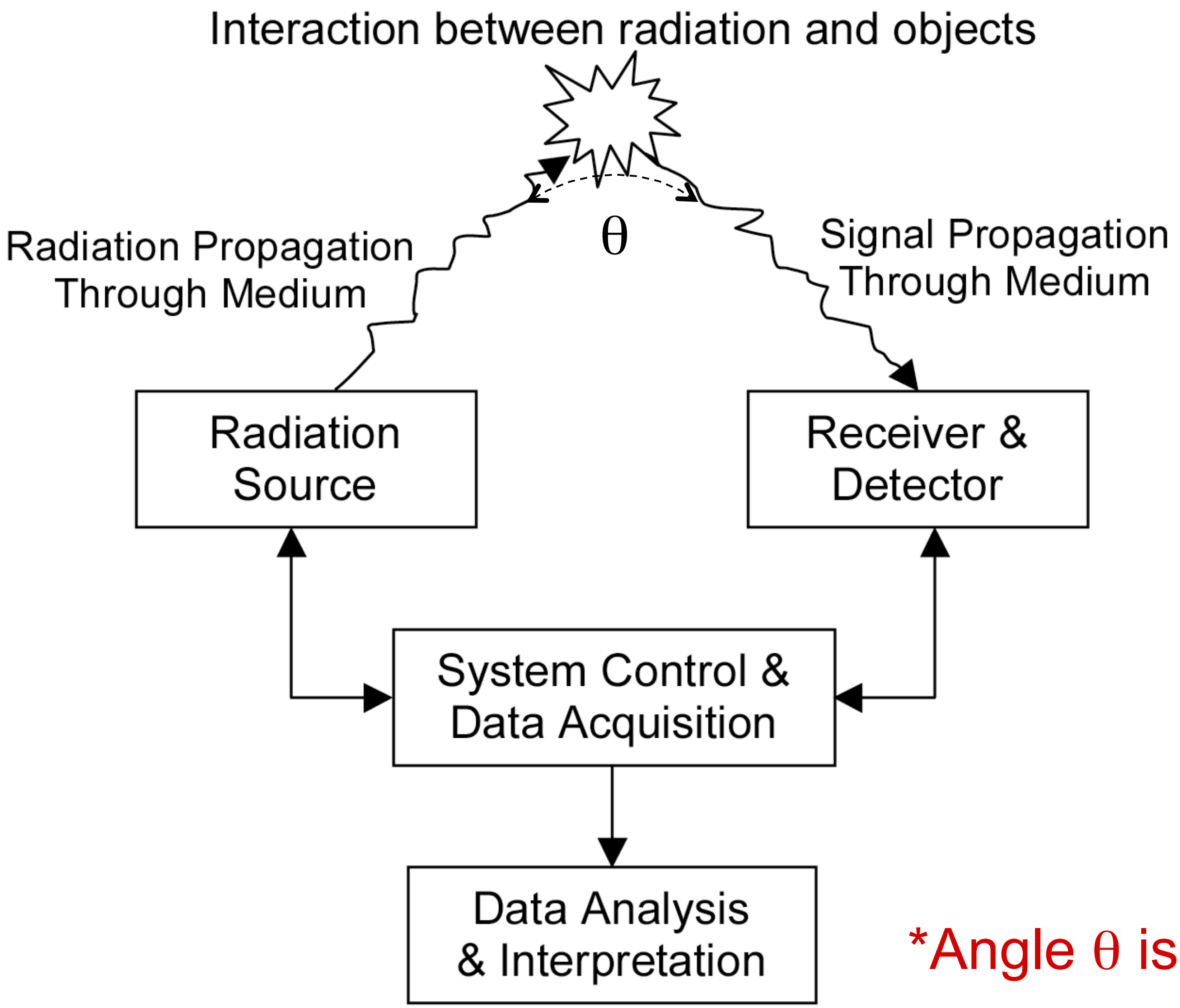
Concept of Remote Sensing

- Remote Sensing is the science and technology of obtaining information about an object without having the sensor in direct physical-contact with the object.
- Remote sensing is opposite to *in situ* methods that obtain information locally.
- The Nature of Remote Sensing is one kind of measurements.
- Measurements are to obtain or acquire information of an object using experimental methods.
- There must be some interaction between the object and the instruments in order to acquire the information of the object.

Concept of Remote Sensing

- The interaction can be direct (local) or remote.
- Without direct physical contact between the sensor and the object, some remote interaction must be introduced to carry away the object information so that the information can be acquired by the sensor remotely.
- The interaction between radiation and the object is the most common interaction used in modern remote sensing.
- The radiation includes electromagnetic radiation and acoustic waves.

Picture of Remote Sensing System

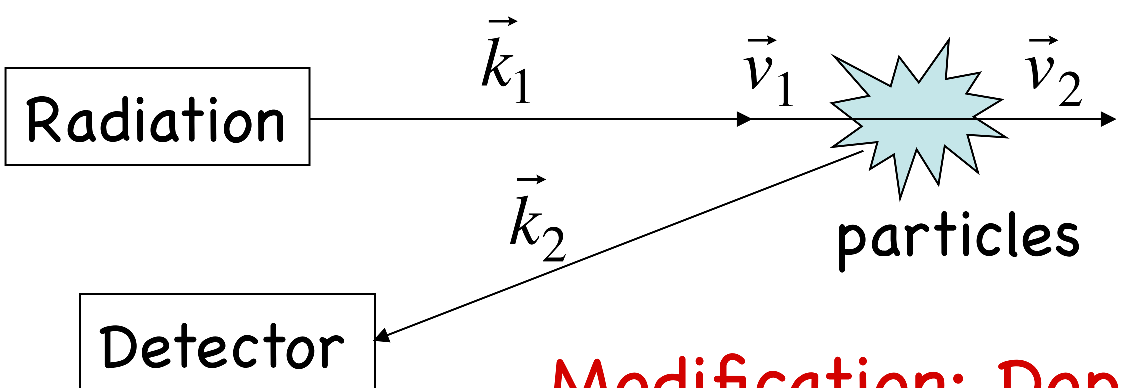


*Angle θ is arbitrary

Concept of Remote Sensing

- During the interaction, radiation properties are modified by the object, therefore, containing the information of the object. Through recording and analyzing the modifications of the radiation, the object information can be retrieved.

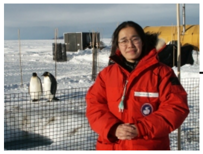
An example: the wind measurements



Radiation is scattered by particles

Modification: Doppler Shift

$$\Delta\omega = \omega_2 - \omega_1 = -(\vec{k}_1 \bullet \vec{v}_1 - \vec{k}_2 \bullet \vec{v}_2)$$



Content of Remote Sensing

➢ Remote Sensing contains many aspects, not only the instrumentation and data acquisition, but also the data processing, analysis, and interpretation.

1. Physical Science and Technology Development:

    physical interaction and principle study,

    instrument design, development, & test/calibration

2. Observational campaigns and missions:

    system deployment, data collection,

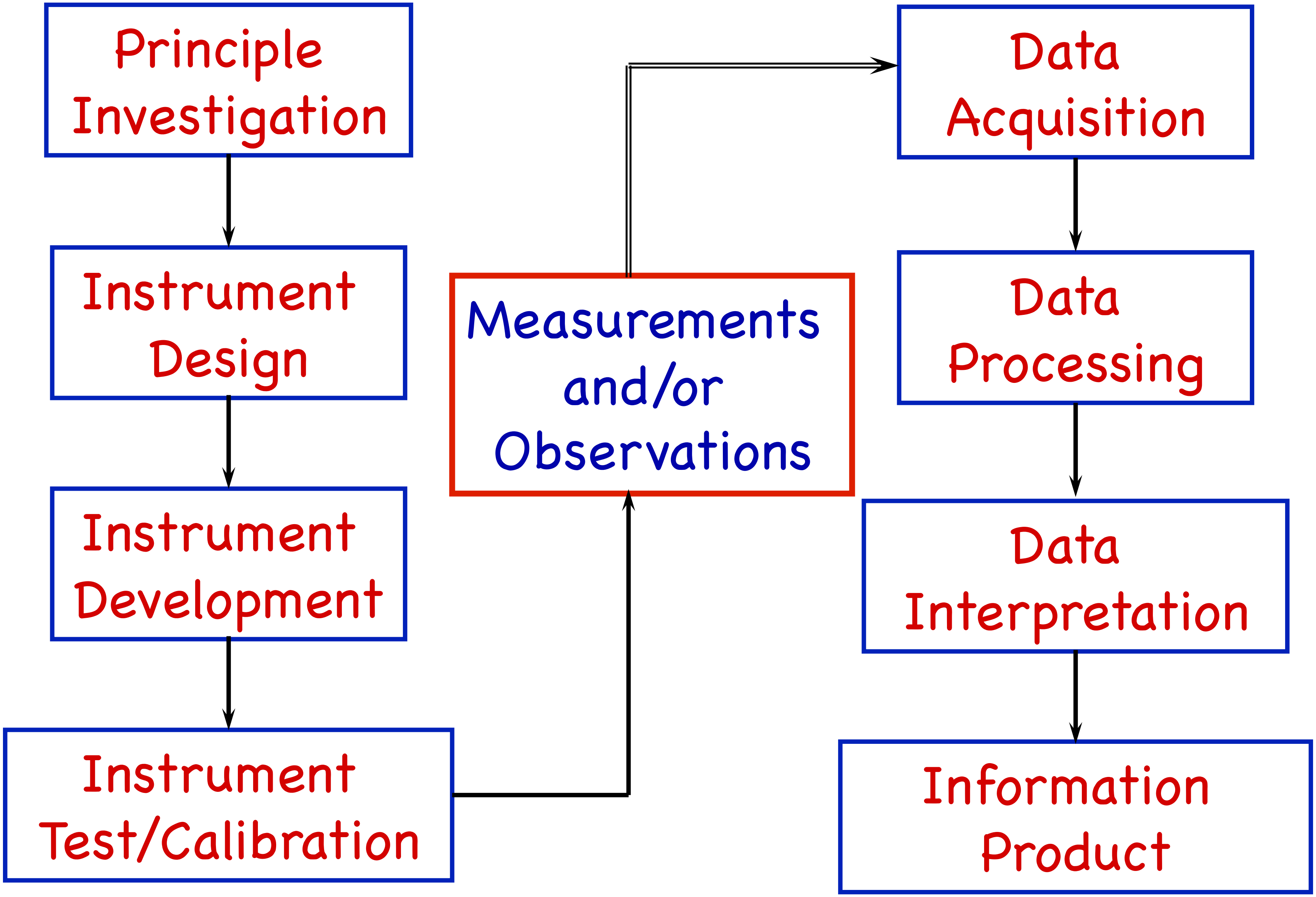
3. Data/signal Processing:

    data processing, information retrieval, error analysis

4. GeoScience Study:

    data analysis and interpretation.

Content of Remote Sensing



Remote Sensing Applications

- Atmospheric Research
- Environmental Research and Industry
- Space Research and Industry
- Solid-Earth Research and Industry
- Ocean Research and Industry
- Space Exploration
- Astronomy Exploration
- Industry, Defense, Military
- and many more …

Advantages of Remote Sensing

- Reaching inaccessible/difficult regions to make reliable measurements
- Avoiding hazardous to reach regions
- Fast and inexpensive probing of large volumes
- Minimal disturbance of measured processes
- …

Remote Sensing Classification 1

- **Passive Remote Sensing**: no self-generated radiation is used in the sensing, but using naturally occurring radiation, such as sunlight or nightglow emission.

- **Active Remote Sensing**: self-generated radiation sources are used, such as laser light, radio- and micro-wave, acoustic wave.

Depending on whether a human-generated radiation source is used in the sensing process

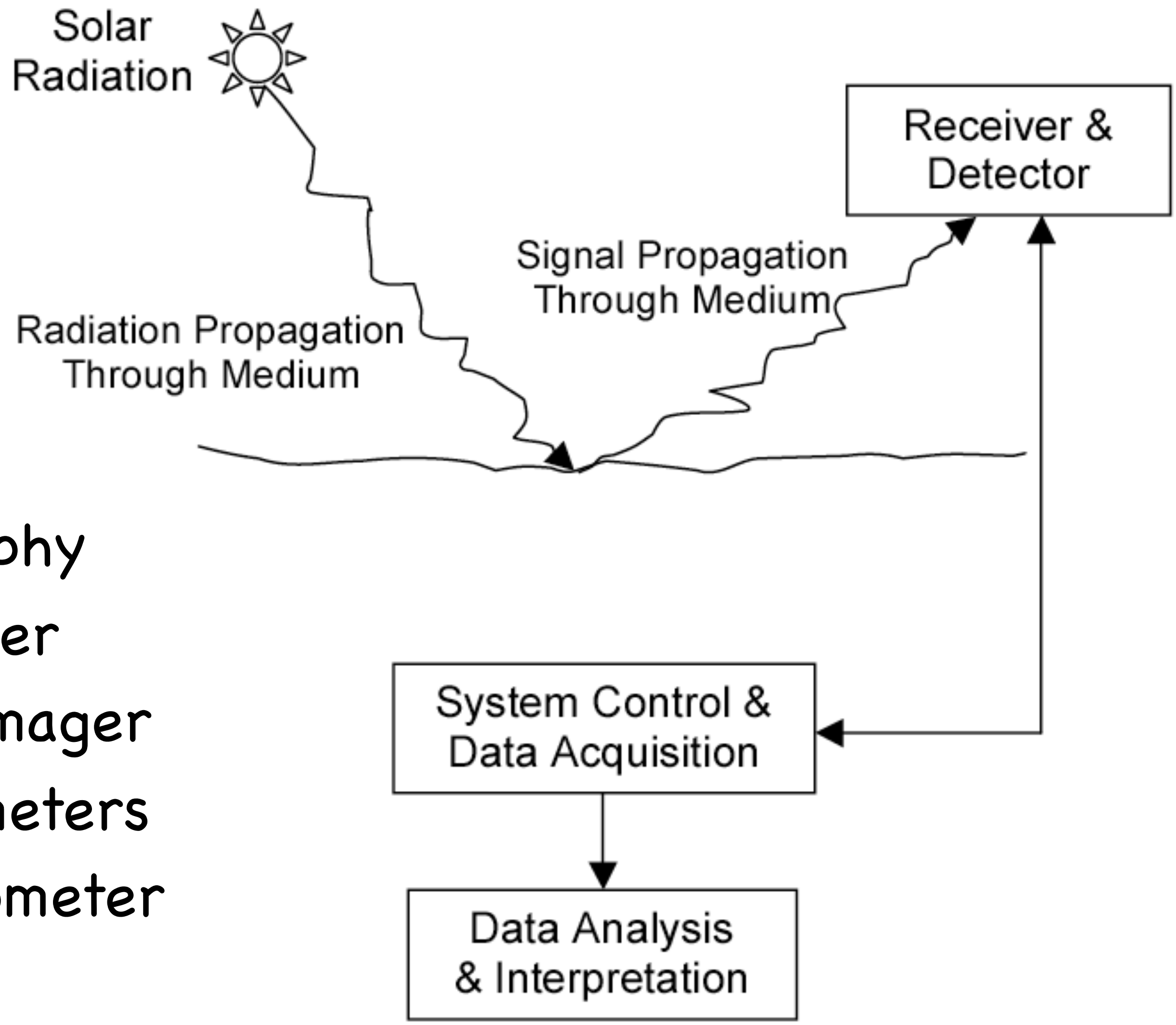
Remote Sensing Classification 2

- Optical Remote Sensing: probing and detecting in optical frequency range
- Radio Remote Sensing: probing and detecting in radio and microwave frequency
- Acoustic Remote Sensing: probing and detecting in acoustic frequency range

All include passive and active remote sensing

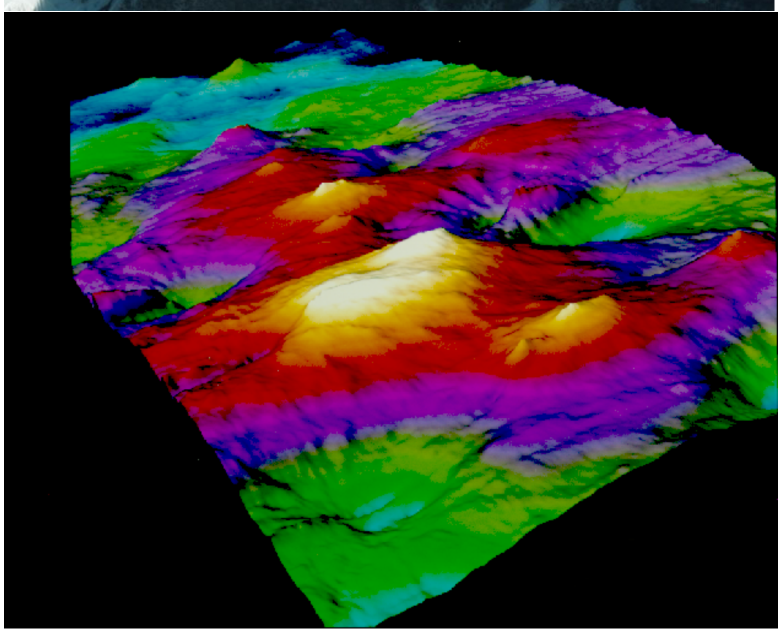
Depending on the frequency of radiation used in the probing and detection

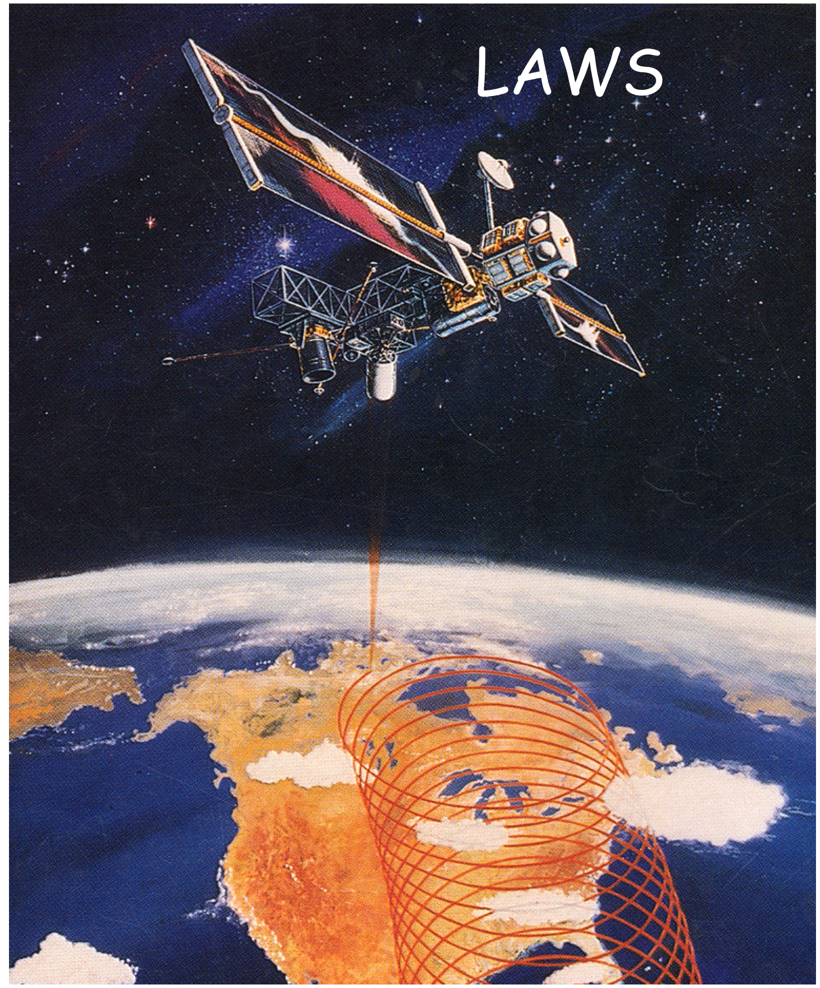
Passive Remote Sensing (Scattering/Reflection)



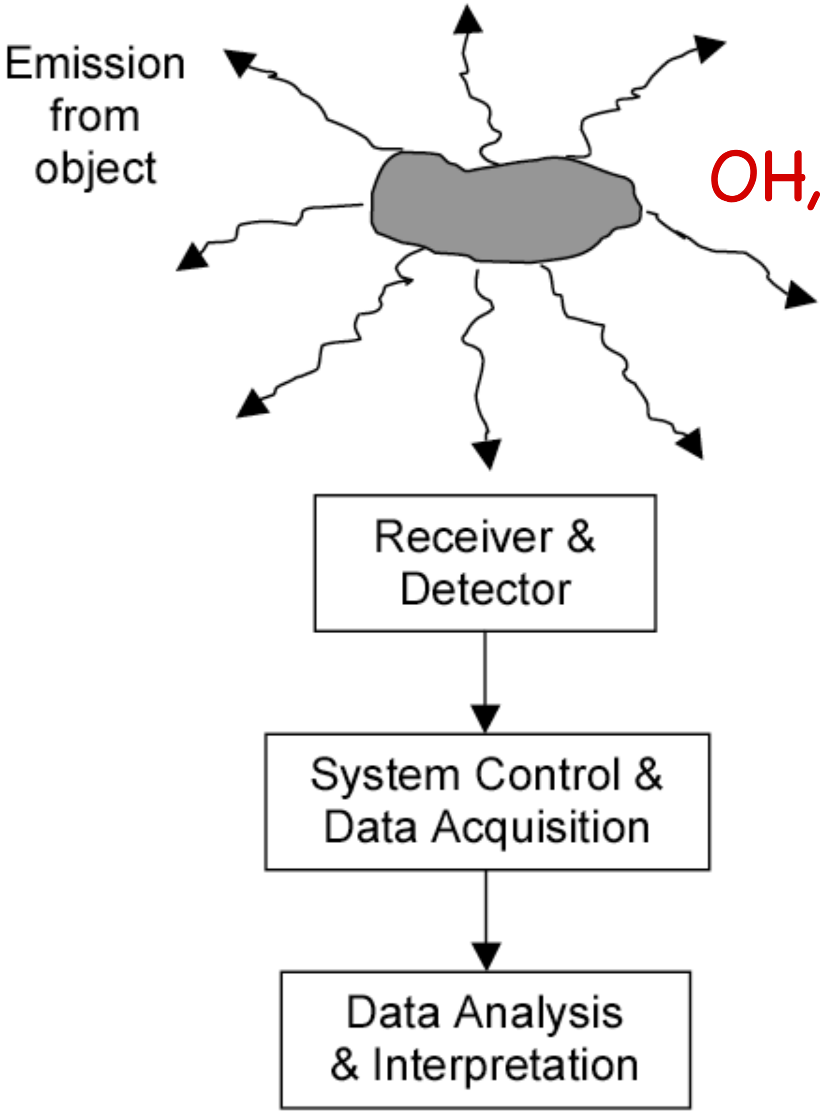
- Photography
- Radiometer
- All-sky-imager
- Spectrometers
- Interferometer
- …

Example: Space Imaging (Scattering)

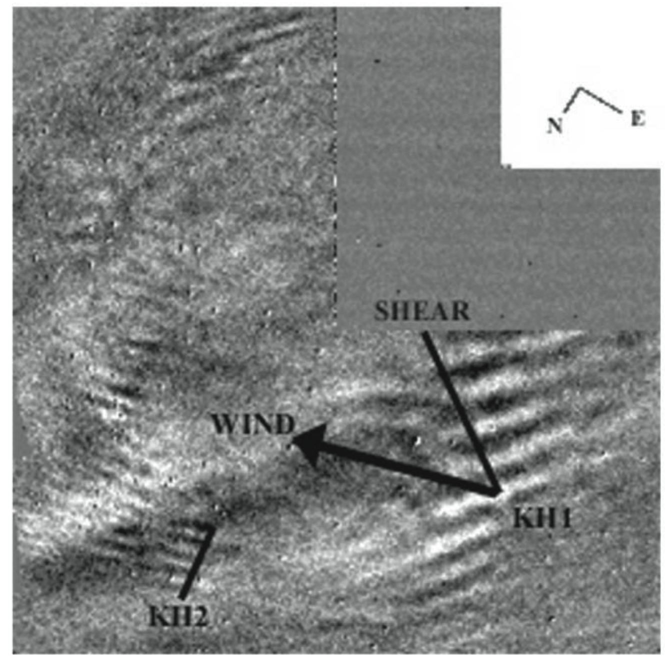




Passive Remote Sensing (Emission)

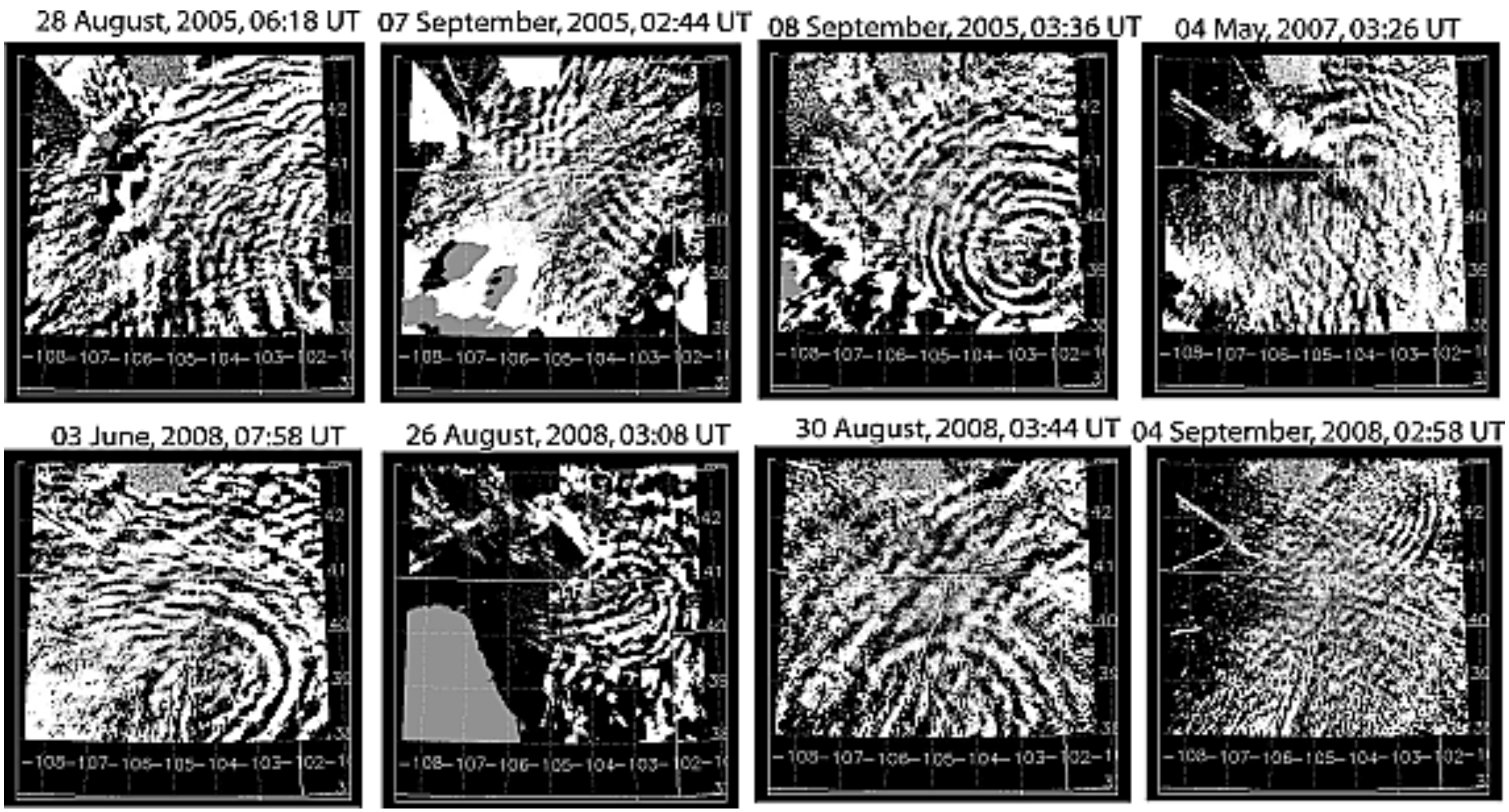


OH, Na, O, etc.



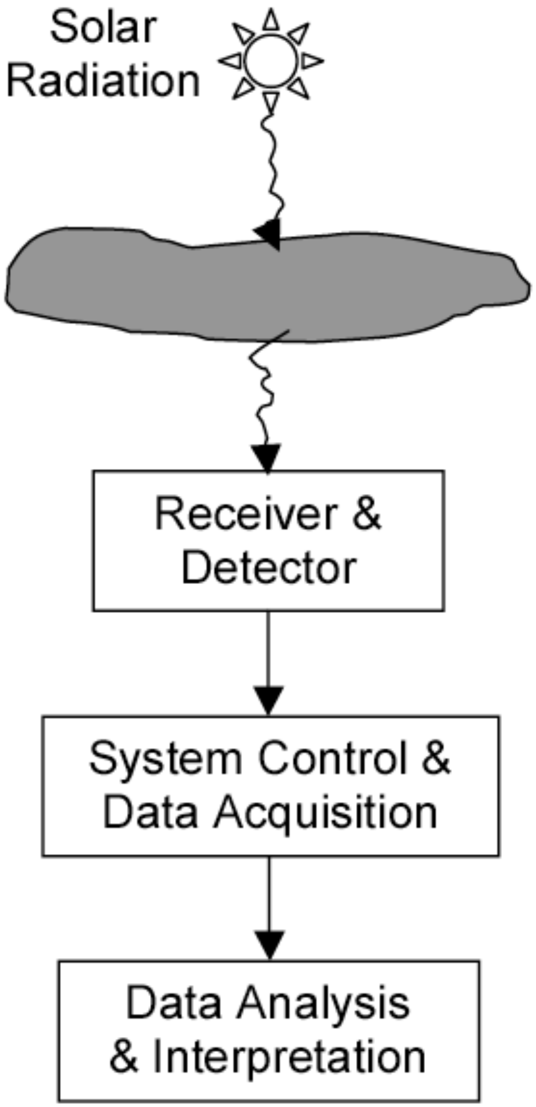
Emissions from
OH, Na, O, etc

Example: All-Sky-Camera (Emission)



OH images show concentric gravity waves (concentric rings) formed by deep convection -- [Yue et al., JGR, 2009]

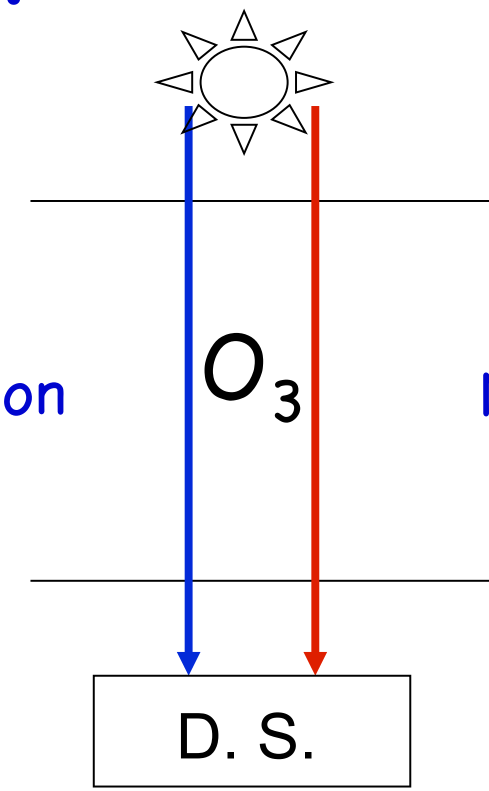
Passive Remote Sensing (Extinction)



NOAA Dobson Spectrometer
to measure ozone
from the ground

Dobson Spectrometer (Extinction)

305 nm
Strong Absorption
by ozone

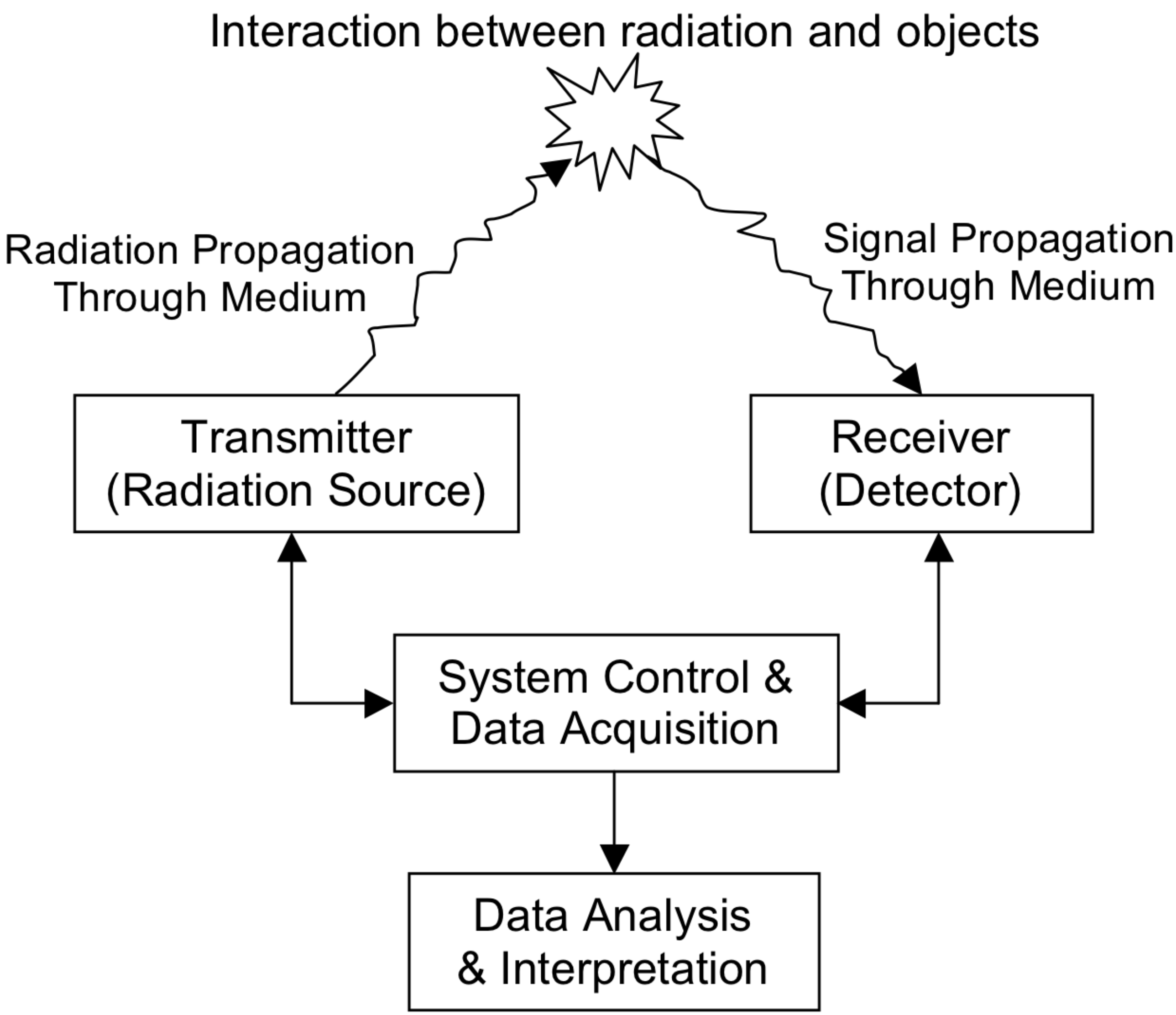


325 nm
No Absorption
by ozone

$$R = \frac{I_{325} - I_{305}}{I_{305}} \propto N_{O_3}$$

The ratio between the two light intensity is a measure of the total amount of ozone in the light path from the sun to the observing D.S.

Active Remote Sensing



Active Remote Sensing

From Biological Sonar

To SODAR, RADAR, LIDAR

SODAR: Sound Detection And Ranging

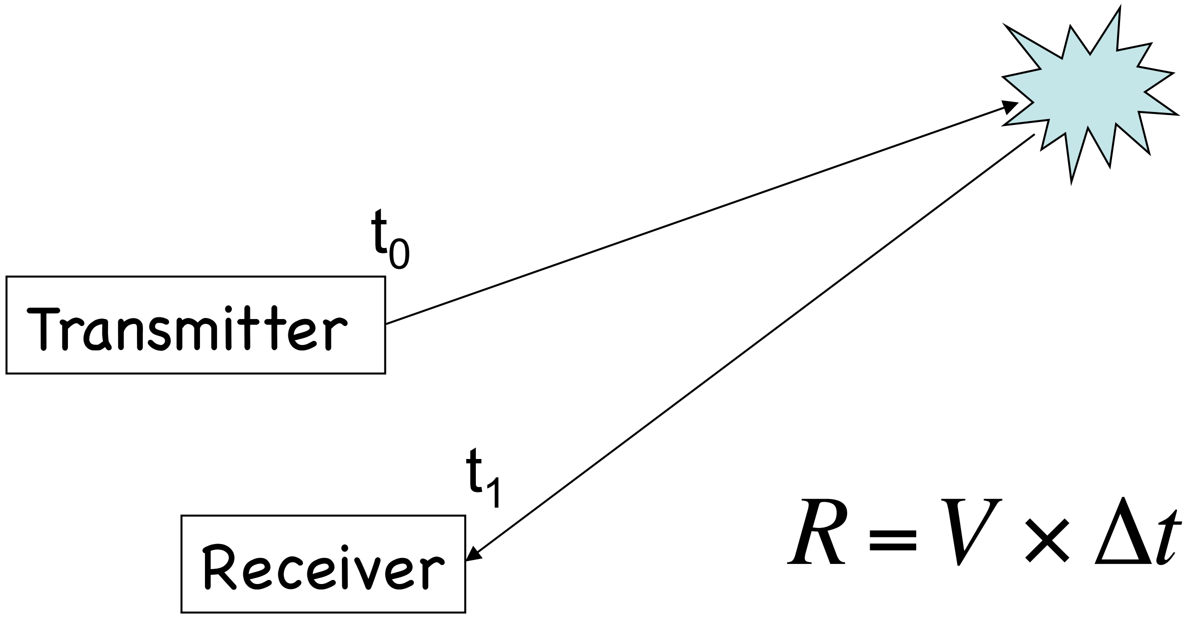
RADAR: Radiowave Detection And Ranging

LIDAR: Light Detection And Ranging

Based on the Same Principle

Radiation is transmitted into environment, backscattered by the objects, and then detected and analyzed by receivers.

How does sodar, radar & lidar work?



$$R = V \times \Delta t / 2$$

Where $\Delta t = t_1 - t_0$, i.e., the time of flight

For radar and lidar, V = c, i.e., the light speed

For sodar, V = the sound speed

SODAR (Sound Detection and Ranging)

Desert Research Institute Doppler SODAR

http://www.dri.edu/Projects/Radar/SODAR/

SODAR (Sound Detection and Ranging)

Atmospheric Research LTD SODAR at Airfield

http://www.a-research.com.au/sodar.html

Three directions are measured with the SODAR so that the 3 components (u, v, w) of wind field can be derived

SODAR & SONAR

- Sound wave or acoustic wave is used in the sensing. This is real mechanical sound wave, i.e., longitudinal wave, produced by compressing the atmosphere medium. It is not electromagnetic wave at the sound frequency.
- The speed used is the speed of sound (340 m/s).
- SODAR works better in the air with more moisture, rather than the dry air. Usually, it goes up to several hundred meters.
- SONAR is Sound Navigation Ranging, used under water, for the ocean detection, like submarine.
- SODAR is usually referred to the sound detection and ranging in the atmosphere. We use it for general description of SODAR and SONAR.
- SONAR works better under water.

RADAR (Radiowave Detection and Ranging)

- Electromagnetic waves in the radio frequency and microwave frequency range are used in the sensing.
- The speed used is the light speed (3×10^8 m/s).

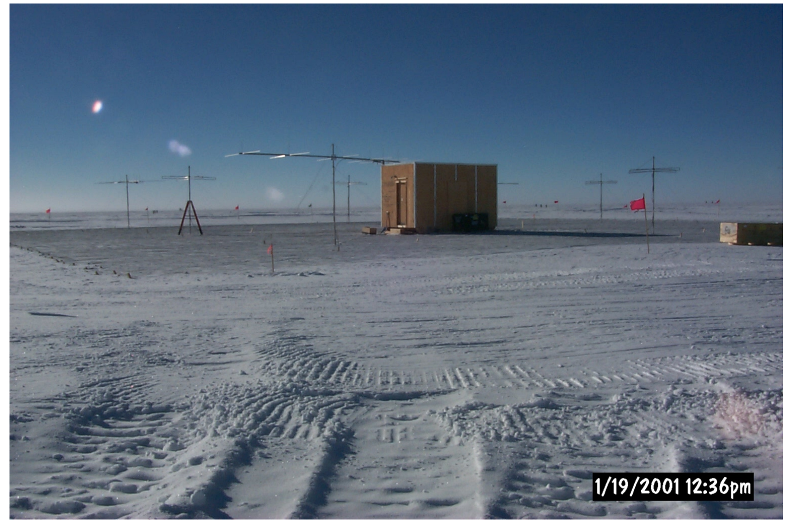
Recommend --

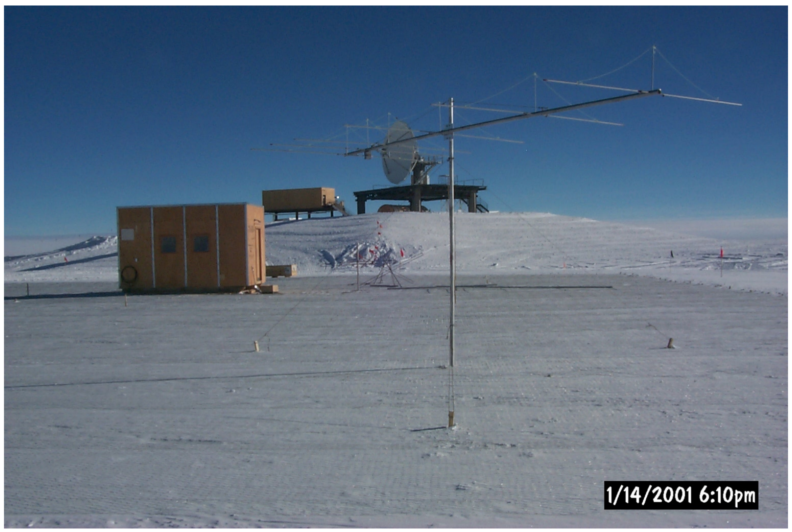
ASEN5245. Radar and Remote Sensing

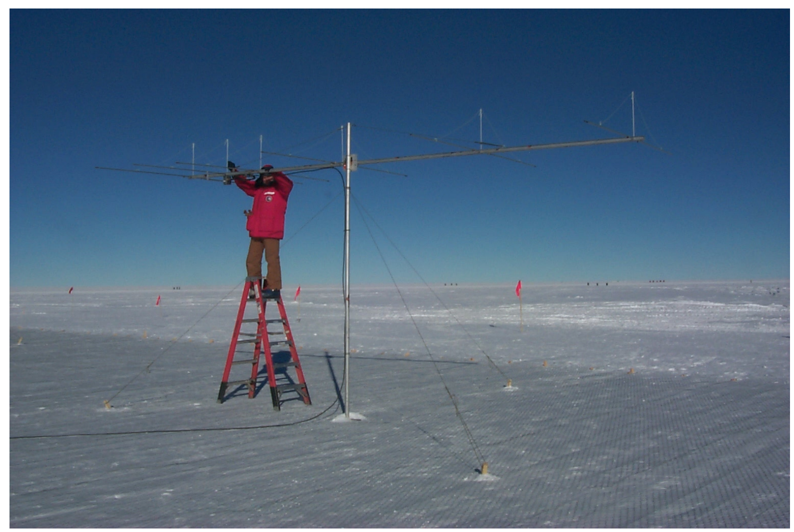
Taught by Prof. Scott Palo or Prof. Jeff Thayer

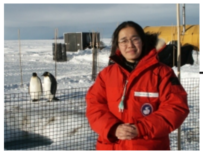
NEXRAD Weather Radar System

South Pole Meteor Scatter Radar

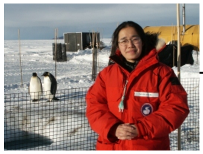




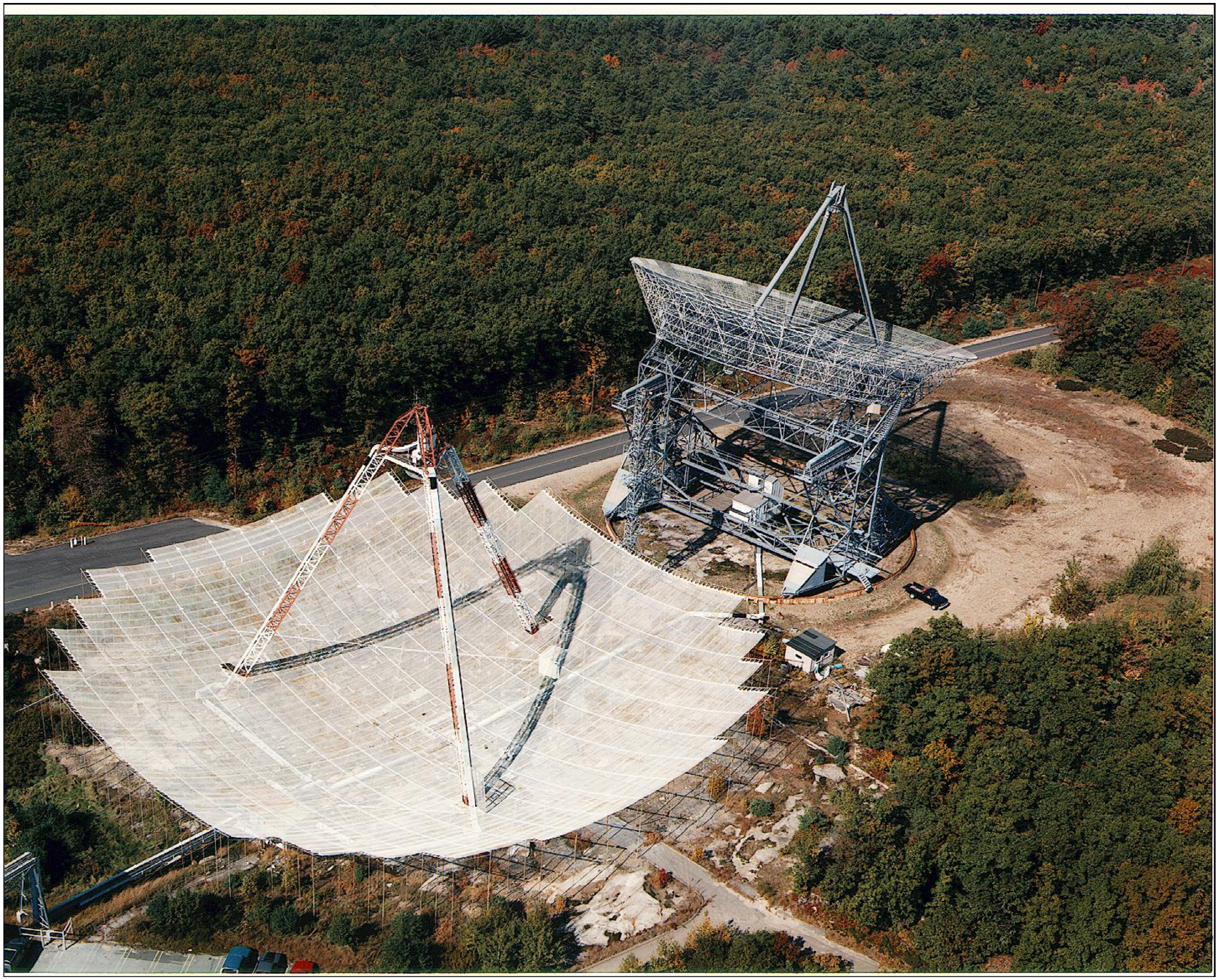




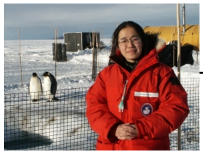
Arecibo Incoherent Scatter Radar



Millstone Incoherent Scatter Radar

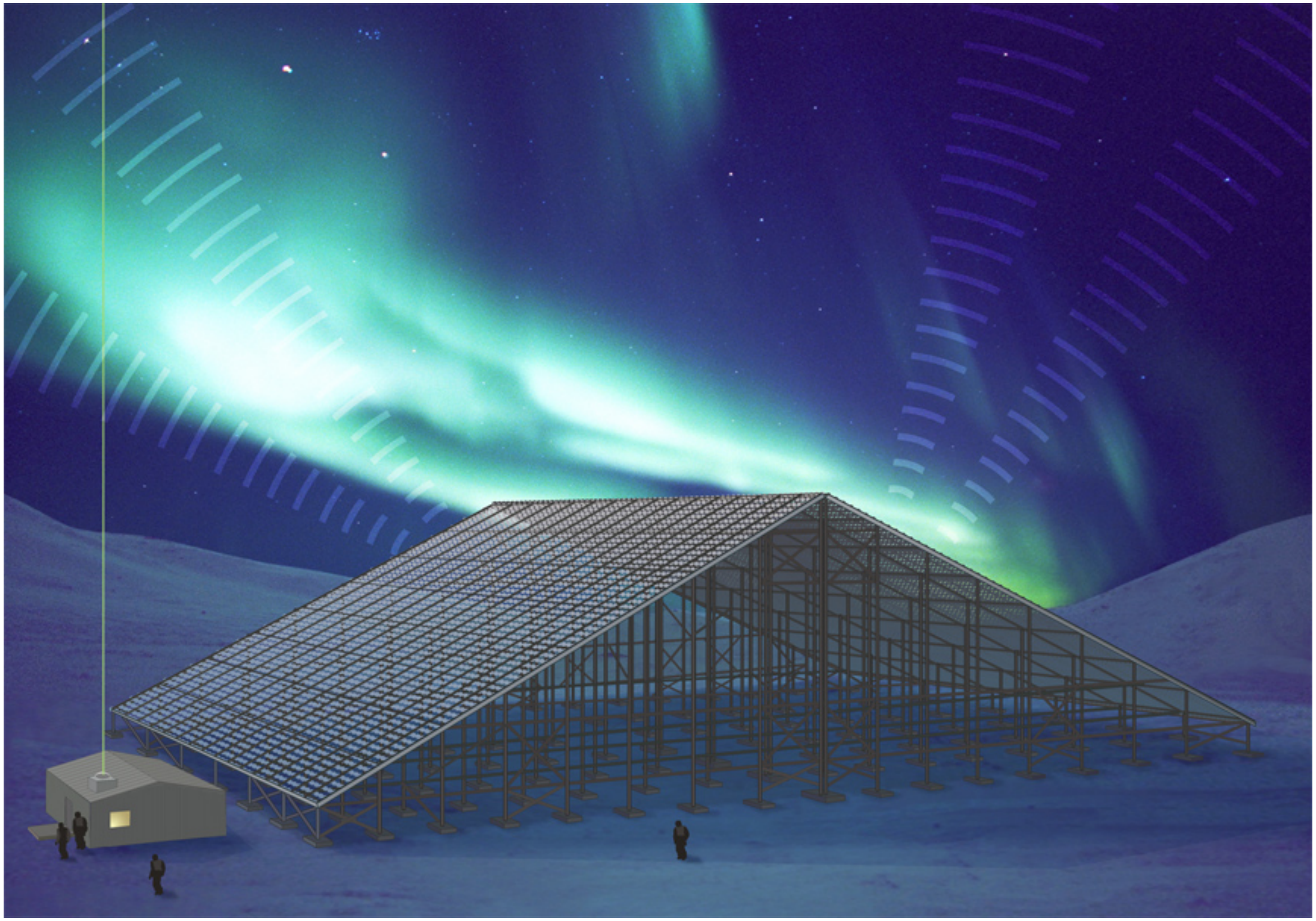


Jicamarca Incoherent Scatter Radar



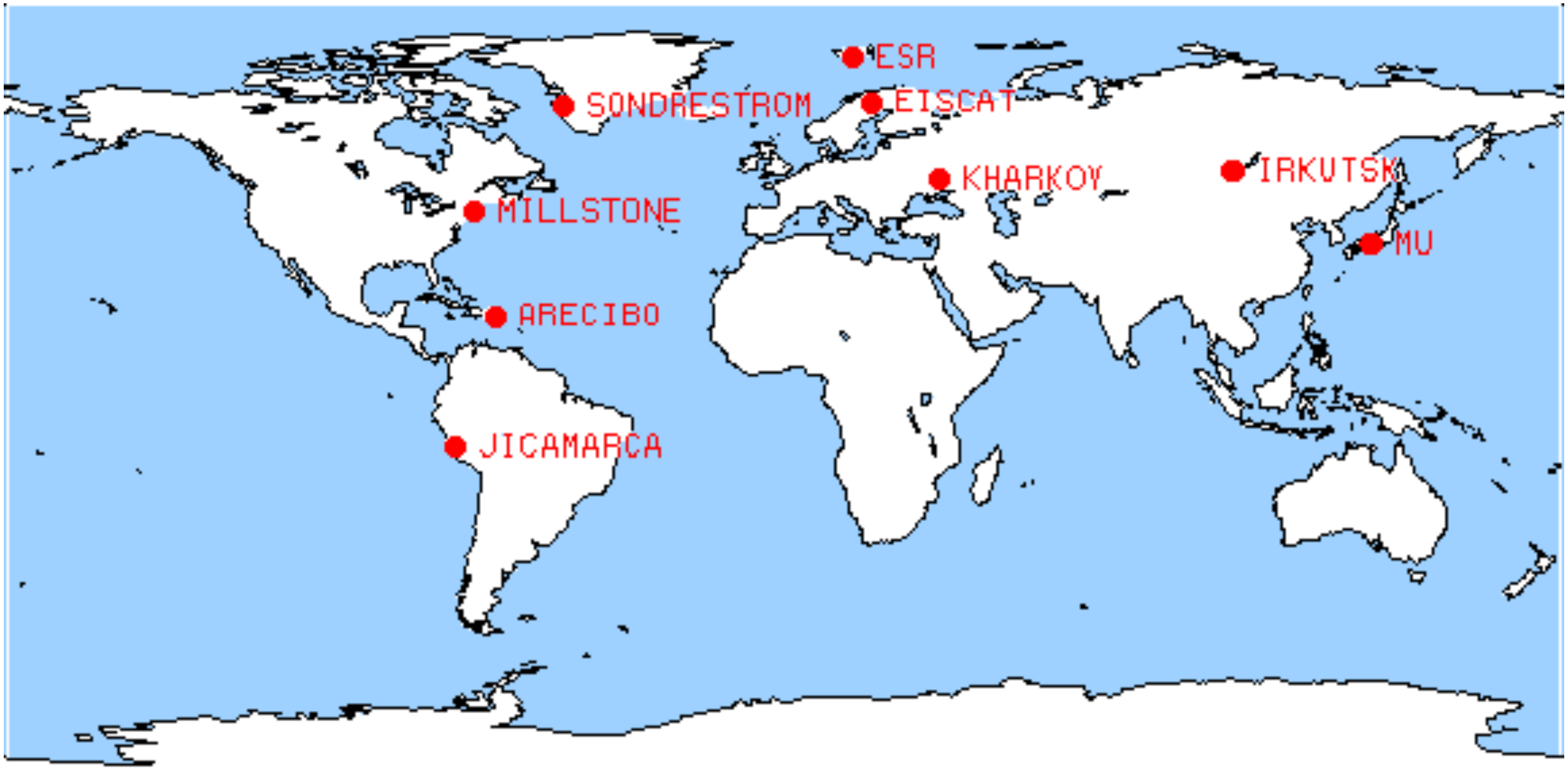
Sondrestrom Incoherent Scatter Radar

AMISR - Advanced Modular Incoherent Scatter Radar



Resolute Bay, Canada and Poker Flat, Alaska

Incoherent Scatter RADAR Map



An incoherent scatter radar may be installed at McMurdo, Antarctica in the future.

LIDAR (Light Detection and Ranging)

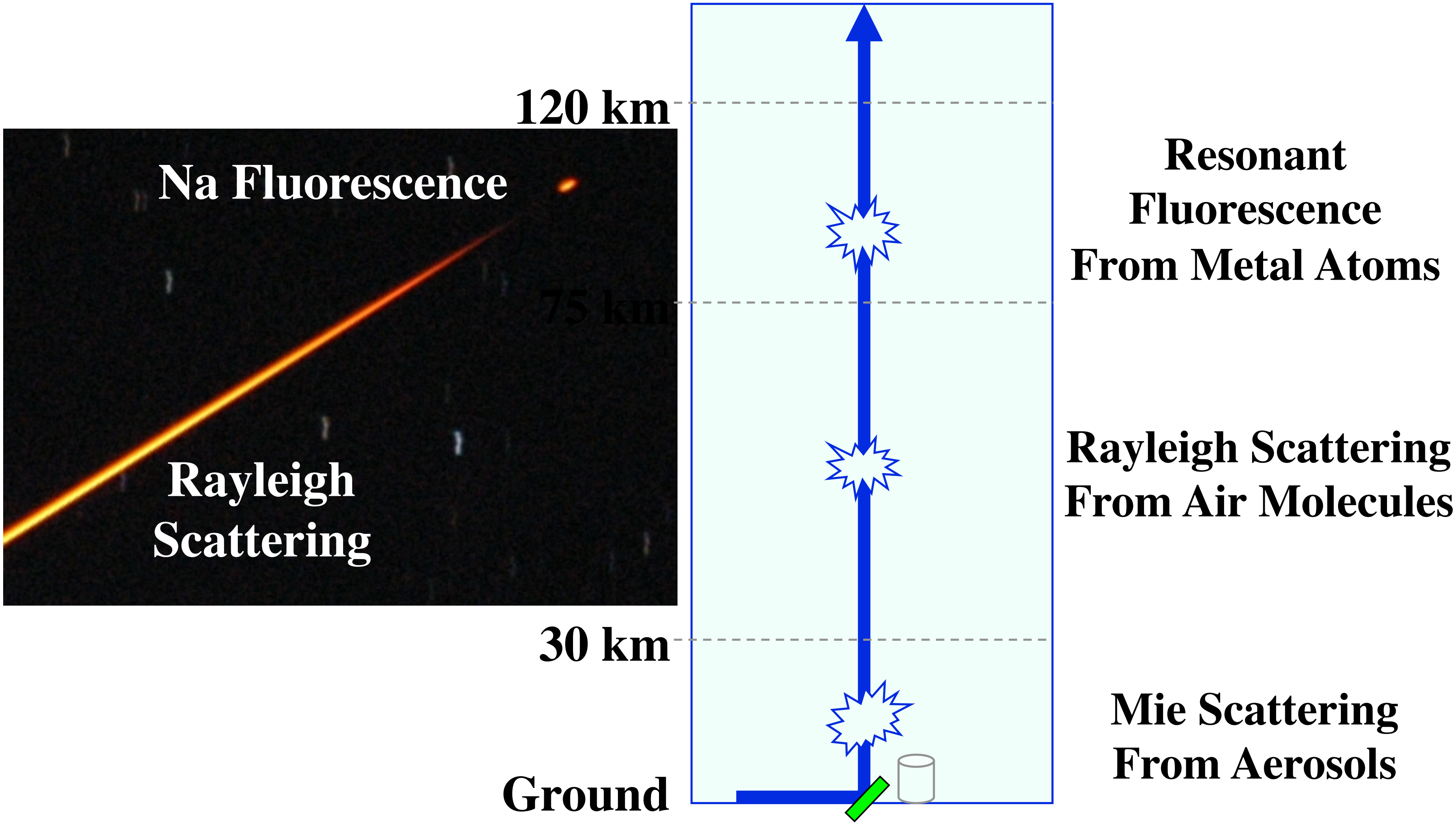
- Electromagnetic waves in the optical frequency range are used in the sensing.

- More commonly, we say light, especially laser light, is used in the sensing.

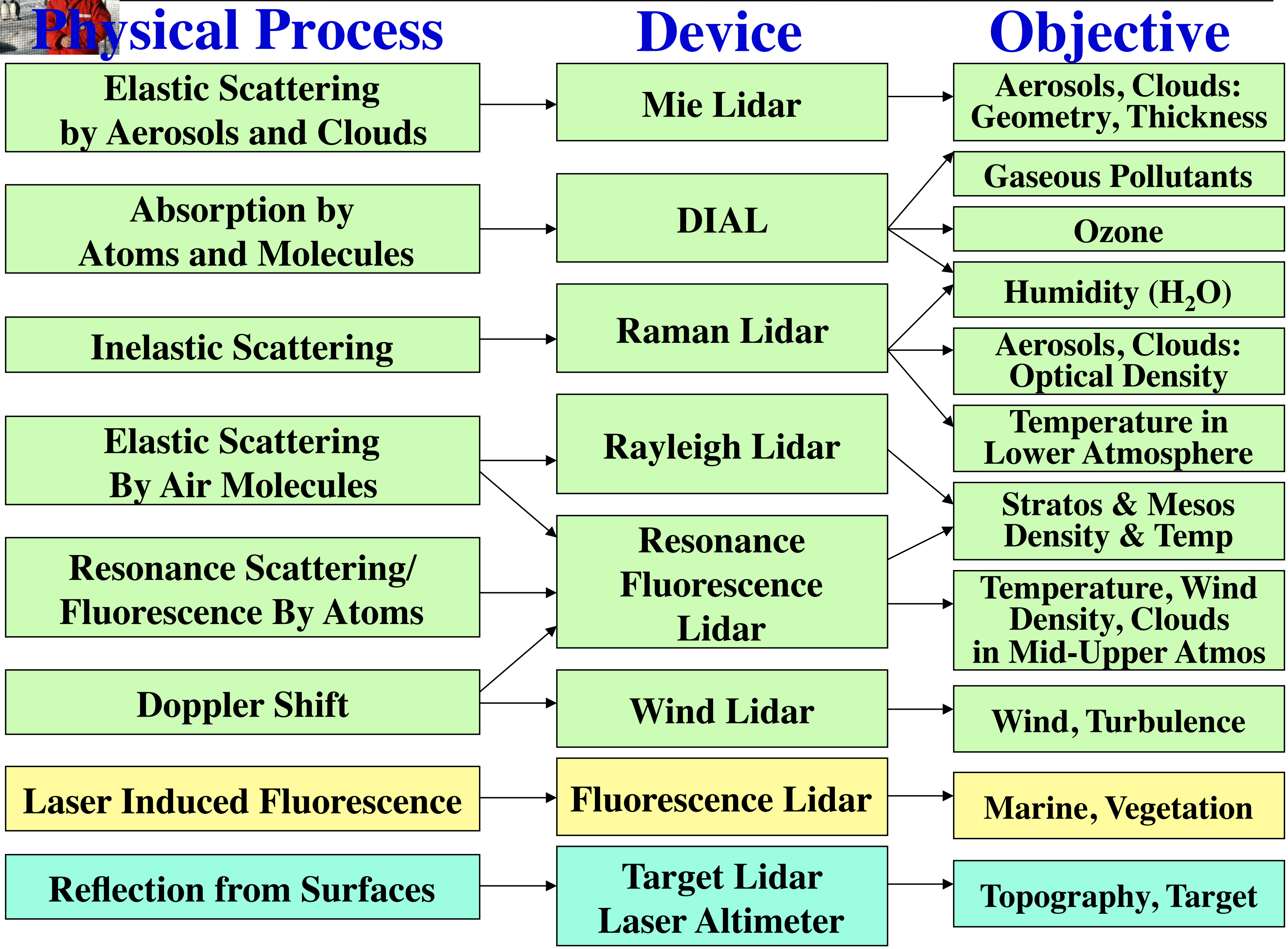
- The speed used is the light speed (3×10^8 m/s).

  c = 299792458 m/s in vacuum

Light Detection And Ranging (LIDAR)



Range Determined From Time-of-Flight: $R = c \cdot \Delta t / 2$


Physical Process
Device
Objective
Elastic Scattering by Aerosols and Clouds
Mie Lidar
Aerosols, Clouds: Geometry, Thickness
Absorption by Atoms and Molecules
DIAL
Gaseous Pollutants
Ozone
Humidity (H_2O)
Inelastic Scattering
Raman Lidar
Aerosols, Clouds: Optical Density
Temperature in Lower Atmosphere
Elastic Scattering By Air Molecules
Rayleigh Lidar
Stratos & Mesos Density & Temp
Resonance Scattering/ Fluorescence By Atoms
Resonance Fluorescence Lidar
Temperature, Wind Density, Clouds in Mid-Upper Atmos
Doppler Shift
Wind Lidar
Wind, Turbulence
Laser Induced Fluorescence
Fluorescence Lidar
Marine, Vegetation
Reflection from Surfaces
Target Lidar Laser Altimeter
Topography, Target

Potential Final Projects

1) Resonance Fluorescence Doppler lidar
2) High-spectral-resolution lidar
3) Direction-detection wind lidar (or with edge filters)
4) Coherent Doppler lidar
5) Laser altimeter
6) Raman lidar
7) Differential absorption lidar (DIAL)
8) Polarization lidar
9) Rayleigh/Mie lidar
10) Fluorescence lidar ……

- Overview of principles, history, and current status
- Design of a lidar system
- Simulation of expected lidar signals
- Sensitivity or error analysis
- Applications

Hardware of SODAR,RADAR, LIDAR

	SODAR	RADAR	LIDAR
Transmitter	Electric-acoustic converter	Electronic circuit + Antenna	Laser
Receiver	Headphone	Antenna	Optical telescope + Photo detector
Transmitted Energy	Acoustic Energy	Electromagnetic Waves	Light

Comparison of Remote Sensing

	Passive			Active	
	Scattering	Emission	Extinction	Scattering	Extinction
Optical	Aerial / Space Photography UARS satellite AIM/CIPS	Airglow Imager Bomem Spectrometer Fabry-Perot Interferometer TIMED/SABER	Dobson Spectrometer UARS/HALOE Occultation AIM/SOFIE	LIDAR	DIAL
Radio		Passive Radiometer	Passive Radiometer	RADAR	GPS Radio Occultation
Sound			Seimograph	SODAR	

Advantages of Active Remote Sensing

- independence of natural radiation sources and time of day;
- reduced sensitivity to background light;
- high intensity of stimulating signal;
- control of stimulating signal;
- knowledge of stimulating signal;
- capable of line integral, line average, line profile, 2-D coverage, 3-D coverage, 3-D spectrum – all as a function of time
- …

Summary

- Remote Sensing concept & picture
- Nature of remote sensing & measurements
- Classifications of remote sensing
- Passive Remote Sensing
- Active remote sensing
- Comparison of Remote Sensing

> Reference Reading Materials
- Chapter 1 of "Laser Remote Sensing" textbook
- IntroRemoteSensing.pdf and IntroLidar.pdf (at website)
- Searchlight.pdf (at the class website)