Remote sensing is the science of acquiring information about the Earth's surface by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information to obtain a data product.
Basics of RS

- Remote sensing is a means of obtaining earth science data without actually being in the field.
- Remote sensing techniques can be divide into two broad categories:
  - Active radiation
  - Passive radiation
- RS Platforms include:
  - Aerial flights
  - Orbiting satellites
  - Shuttle Missions
  - Earth-based antennas

General Schematic
Remote Sensing is based on ElectroMagnetic energy distributed across various wavelengths or frequencies.

RS technologies vary by the wavelength used.

Choosing an appropriate $\lambda$ depends on the parameter to be measured.

Once a $\lambda$ has been selected, then the appropriate RS technology can be specified.
A clear distinction exist between active and passive techniques:
- Active RS implies directing EM energy towards a target and measuring the reflected energy.
- Passive RS implies receiving the emitted EM energy from a surface without exciting it.

Examples:
- Active RS:
  - RADAR
  - LIDAR
- Passive RS:
  - Visible/IR
  - Microwave

Space-based RS
The microwave energy recorded by a passive sensor can be emitted by the atmosphere, and reflected or emitted from the surface.

The energy available in the microwave spectral band is small compared to thermal and visible wavelengths. Thus large antennas are required to detect enough energy to record a signal.

Most passive microwave sensors are therefore characterized by low spatial resolution.
Active Radiation RS

- **RAdio Detection And Ranging (RADAR)** systems are active sensors which provide their own source of electromagnetic energy.
- The microwave energy backscatter is detected, measured, and timed. The time required for the energy to travel to the target and return determines the distance or range to the target.
- Range and magnitude of return from target allow the construction of a two-dimensional image of the surface.
Hydrological Applications

- Flood mapping and monitoring
- Snow water equivalent and area
- Soil Moisture
- Wetlands
- Land use mapping
- Terrain mapping
For Hydrological modeling, we require data that describes the watershed as a system:
- Soils description
- Land use description
- Topography
In addition, the forcings must be specified:
- Weather data
- Rainfall
Finally, model output is compared to observation:
- Runoff or flood inundation
Remote Sensing can provide these inputs, albeit at resolutions commensurate with the measurement technique.
The Grand Canyon is one of North America's most spectacular geologic features. Carved primarily by the Colorado River over the past six million years, the canyon sports vertical drops of 5,000 feet and spans a 277-mile-long stretch of Arizona desert. The above view was acquired by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument aboard the Terra spacecraft. Visible and near infrared data were combined to form an image that simulates the natural colors of water and vegetation.

Courtesy of NASA
This view shows the capital city of **San Jose, Costa Rica**. Rising behind it are the volcanoes Irazu, 3402 meters and Turrialba, 3330 meters high. This three-dimensional view was generated using topographic data from the Shuttle Radar Topography Mission (SRTM) and an enhanced false-color Landsat 7 satellite image. Colors are from Landsat bands 5, 4, and 2 as red, green and blue. Landsat has been providing visible and infrared views of the Earth since 1972. SRTM elevation data matches the 30-meter resolution of most Landsat images.
Dramatic differences in land use patterns are highlighted in this image of the U.S.-Mexico border. Lush, regularly gridded agricultural fields on the U.S. side contrast with the more barren fields of Mexico. This June 12, 2000, sub-scene combines visible and near infrared bands, displaying vegetation in red. The town of Mexicali-Calexico spans the border in the middle of the image. Watered by canals fed from the Colorado River, California's Imperial Valley is one of the country's major fruit and vegetable producers.

Courtesy of NASA
Passive RS

RS Examples

The images of Cuprite, Nevada were taken by the Airborne Visible and Infrared Imaging Spectrometer (AVIRIS). AVIRIS collects data in 224 spectral bands, ranging from visible blue (0.4 µm) to shortwave infrared (2.5 µm). The large number of closely spaced bands allows geologists to calculate spectra for each pixel of the image, and determine what minerals are on the surface (assuming there’s no vegetation in the way).

Courtesy of NASA
RS Examples

Tropical storm Keith was born in the Caribbean and reached hurricane Category 3 making landfall on Mexico's Yucatan Peninsula with winds of 135 mph. The image on the left is a combination of NOAA GOES and NASA QuikScat data. The white cloud structure was produced using GOES data, while the arrows showing wind speed and direction by QuikScat. The image on the right was created using the Microwave Imager (TMI) aboard NASA's Tropical Rainfall Measuring Mission (TRMM) with the ability to peer within a storm and detect rainfall.
RS Examples

This Moderate-resolution Imaging Spectroradiometer (MODIS) image shows the Zambeze River after flooding. In this false-color image, green shows land areas, the dark blue pixels are water, and the white pixels are clouds. In a repeat of last year's operations in Mozambique, South African search and rescue helicopters were called in to pluck people stranded by the rising river waters. Unfortunately, 52 people have died in this event and more than 85,000 are now homeless.

Courtesy of NASA
Soil Moisture Field Sampling

Nerrigundah Site in New South Wales, Australia

- Intensive Soil Moisture Sampling
- Spatial and Temporal Data
- Topography and Soils Sampling

6 hectares

Walker, Willgoose and Kalma
Field and Remote Sensing of Soil Moisture

- Soil moisture is a critical hydrologic state variable that determines evaporation, runoff and infiltration.
- Measurement of soil moisture is done through field trips.
- We are developing technology that could be used for field sensing of soil moisture.
- Soil moisture can also be remotely sensed from aircraft or satellites.
- Prof. Dara Entekhabi is leading a mission to design, construct, launch and operate a soil moisture instrument.
- Field and Remote Sensing of Soil Moisture can be used in unison for hydrologic modeling. The link between field and remote sensing is strong.
Soil Moisture Field Sampling

Surveyed Topographic Map

Soil Moisture Probes
Soil Moisture Field Sampling

Hydrologic Field Measurements
Soil Moisture Remote Sensing

HYDROS Mission

- Prof. Dara Entekhabi, PI.
- Team from NASA, JPL, GODDARD, other universities.
- Mission is to design a satellite that measures soil moisture and freeze/thaw cycle globally.
- Hydrologic applications anticipated from soil moisture.
- End-to-end mission design and scientific objectives.
- ~200 million dollar mission.

HYDROS: Hydrosphere State Mission
Soil Moisture Remote Sensing

Field Experiments

PBMR

ESTAR

AMSR

SMOS

HYDROS

1970s 1980s 1990s 2000s

June 10
June 11
June 12
June 13
June 14
June 15
June 16
June 17
June 18

< 5 Soil Moisture (%) > 45

10 km

Global mapping (50 km)

High resolution mapping
Active/passive synergy
Measurement of terrestrial surface resistance to flux (soil moisture and freeze/thaw)

Scaling and aggregation

TB Inversion

Measurement of terrestrial surface resistance to flux (soil moisture and freeze/thaw)
Mission Data Flow

- **Ground Receiving Stations**
- **Missions Ops (JPL)**
- **Radar Instrument Team (JPL)**
- **Radiometer Instrument Team (GSFC)**
- **Soil Moisture Data Products Center (GSFC)**
- **Freeze/Thaw Data Analysis Center (University of Montana)**
- **DAAC Center (GSFC)**
- **Soil Moisture Analysis Center (MIT and GSFC)**
- **Distributed Users**

Spacecraft
Land-atmosphere exchanges are strongly influenced by a surface resistance (soil moisture and its freeze/thaw phase) that collectively define terrestrial hydrosphere state that imposes control on evaporation, transpiration and carbon exchange, and is therefore a fundamental determinant of global water, energy and carbon cycles.
HYDROS Scientific Objectives

- Provide new data type that enables investigations into the role of soil moisture and freeze/thaw in regulating terrestrial water, energy, and carbon cycles.
- Map globally soil moisture and freeze/thaw for the purpose of extending the predictive capability for climate and weather events influenced by land surface fluxes.
- Measure the dynamics of soil moisture and freeze/thaw as a constraint on hydrological, meteorological, agricultural, and ecological models.
- Provide a baseline to assess trends in the terrestrial hydrosphere.
HYDROS NASA Objectives

- How are global precipitation, evaporation, and the cycling of water changing?
- How do ecosystems respond to and affect global environmental change and the carbon cycle?
- To what extent can weather forecasting be improved by new global observations and advances in satellite data assimilation?

Soil Moisture affects Climate Models
Soil Moisture affects Evaporation

Soil Moisture affects Carbon Flux

Campbell Yolo Clay Field Experiment Site
Summer 1995, California
HYDROS Value-Added Products
Integrated Passive and Active L-band Sensor
- 1.41 GHz Radiometer; 1.2 GHz Radar

Spatial Resolution:
- Soil moisture: 40 km (hydroclimatology)
- Soil moisture: 10 km (hydrometeorology)
- Freeze-thaw: 3 km (heterogeneity)

Temporal Sampling: (Global revisit)
- 2-3 days globally (soil moisture)
- 1 to 2 days above 45°N (freeze-thaw)

Orbit
- 670 km altitude (coordinates w/ SMOS)
- Sun-synchronous 6 am / 6 pm

Mission Duration
- 3 years minimum, 5 years desired
HYDROS Mission Concept

- **Measurement Approach**
  - Microwave, L-Band
  - Passive Radiometer
    - Sensitive to soil moisture, mature
  - Active Radar
    - Higher res soil moisture
    - Freeze/Thaw Detection

- **System Concept**
  - 6.5 meter, conically scanning deployed mesh antenna
    - Radiometer/Radar share aperture
    - Wide-Swath
  - 670 km, 6 am, sun-synchronous orbit.
HYDROS Instrument Concept

**Integrated Passive and Active L-band Sensor**

**Radiometer:**
- Frequency: 1.41 GHz
- 3-day global coverage
- Resolution: 40 km
- Polarizations: V, H, and U
- Precision/stability: 0.2 K / 0.5 K

**Radar:**
- Frequency: 1.2 GHz
- Coverage: High resolution mode: 1-2 days above 45°N
- Resolution: High resolution 1-3 km
- Polarizations: VV, HH, HV
- Accuracy: 0.5 dB / 0.2 dB

**Instrument Characteristics**
- Power: 786 W peak, 524 W average
- Mass: < 230 kg total
- Data Rate: 16 Mbps (peak)
HYDROS Antenna Design

- **Antenna**: 6-m-diameter mesh
- **Rotation rate**: 7 rpm
- **Orbit**: 6-am/pm sun-synchronous
- **Altitude**: 670 km
- **Incidence angle**: 40° (constant)
- **Swath width**: 1000 km
- **Global coverage**: 2-3 days (1-2 40 N+)
- **Mass**: <650 kg
- **Data Rate**: 16 Mbps peak
- **Spacecraft Provider**: SpectrumAstro
HYDROS Coverage

Three-day coverage at 6 am

Radiometer and Low-Res Radar

High-Res Radar
Remote Sensing is a new tool for environmental engineers and earth scientists.

RS Technologies span a range of platforms and instruments.

Many professions combine to make space-based RS possible.

A hydrological mission for soil moisture sensing is currently in a proposal and conceptual design phase.

Consider RS as a possible source of data or even a career path!