Introduction to Remote Sensing for Decision Making

National Centers for Environmental Information (NCEI)

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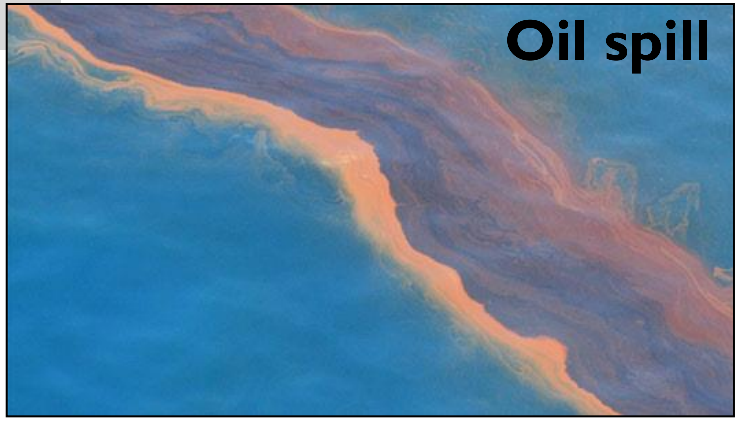
Outline

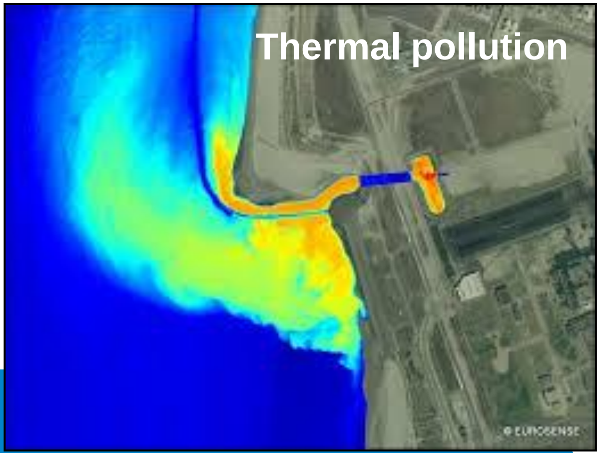
- Information-based decision making
- Introductory remote sensing
- Remote sensing for decision making
  - Tools
  - Strategies

Ocean and coastal issues/challenges

- Resource depletion (e.g., overfishing, IUU)
- Climate change
- Erosion
- Pollution – coastal & offshore
- Vessel monitoring
- Piracy & maritime security
- Construction & coastal development


Oil spill


Algal bloom


Thermal pollution


Offshore drilling, Nigeria

West Africa maritime security activities

Information-based decision making

Environmental decision making:

- *selection* of a course of action among *several possible alternative* options to yield a *satisfactory* or *optimal* solution

- decisions geared towards mitigating current problems and securing the blue planet for future generations.

- the **A**^{3} guide:

Approaches to decision making

1. Consider the situation as a whole.
2. Set objectives: identify the decision(s) that need(s) to be made
3. Classify objectives and place them in order of importance
4. **Collect data on the range of alternatives.**
5. Develop criteria for assessment of the alternatives.
6. Assess the alternatives against all the objectives.
7. Choose one alternative.
8. Monitor the outcome of the decision.

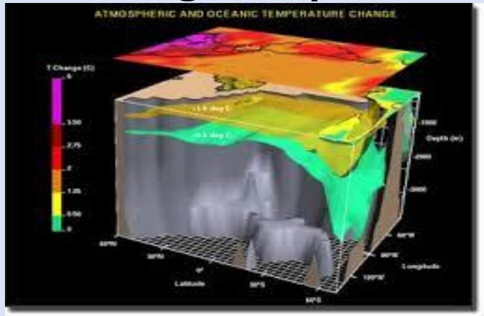
Need for information/data-driven decision making

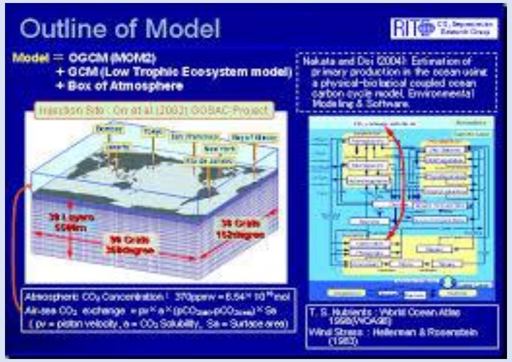
- Environmental decisions historically relied too heavily on educated guesses but not hard facts
- This allows critics to dismiss the severity of environmental pollution and needs for resource management
- Objective, verifiable information allows for robust, unambiguous, and transparent environmental decision making
- Identify gaps and assess priority areas
- Better assess environmental change and performance for improved policy choices
- Information-based decision making improves environmental management processes

Sources of ocean and coastal data/information

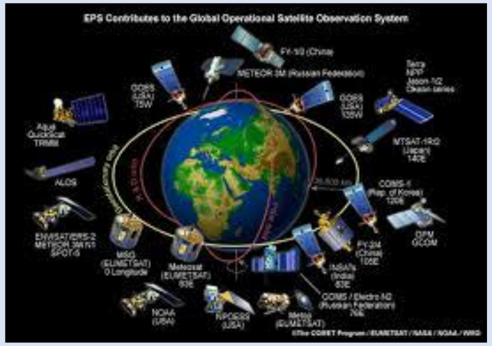
In-situ data:

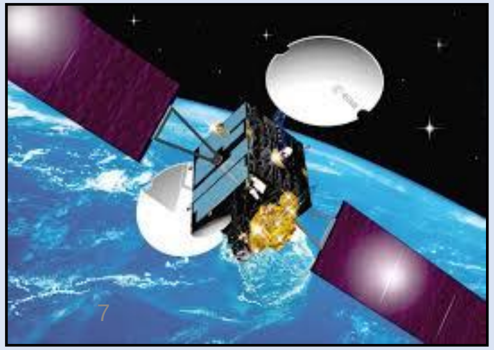
Modeling outputs:





Satellite data:





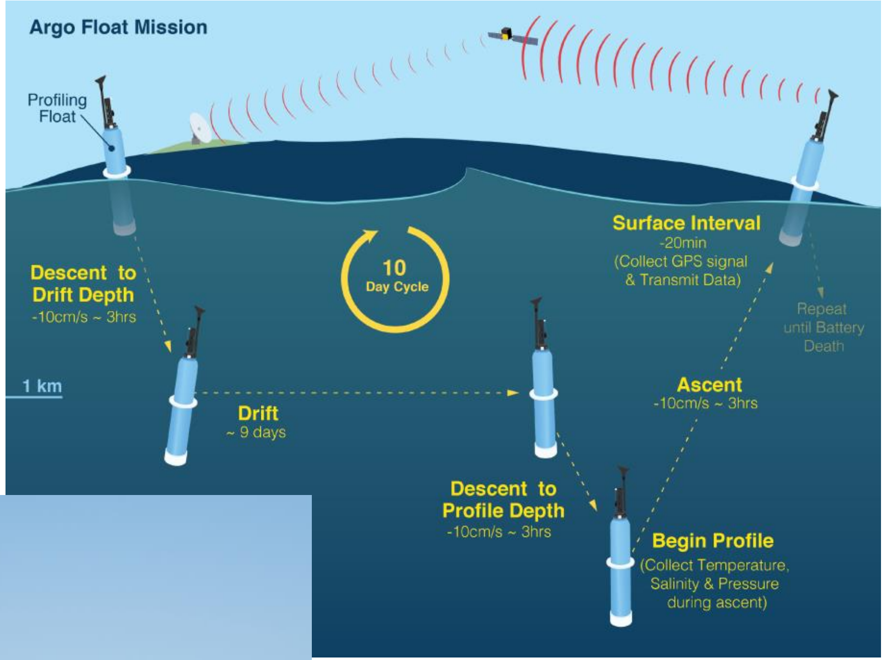
Sources of ocean and coastal data/information

- Gathering ocean and coastal information is

  time-consuming

  often difficult

  often expensive



Characteristics of good data

Sources of ocean and coastal data/information

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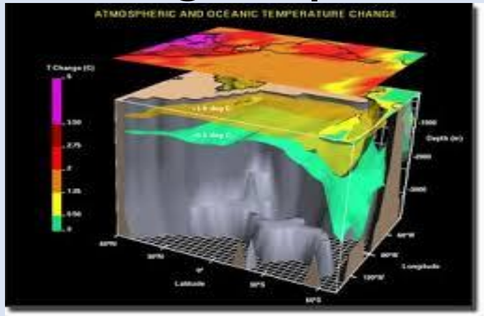
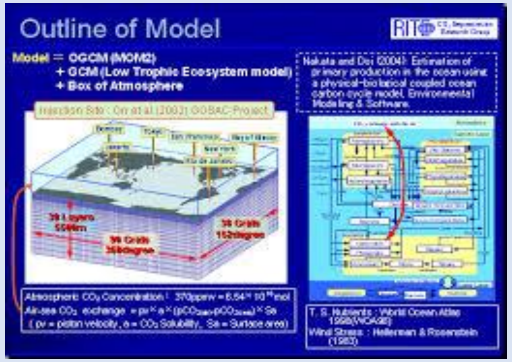
Modeling outputs:





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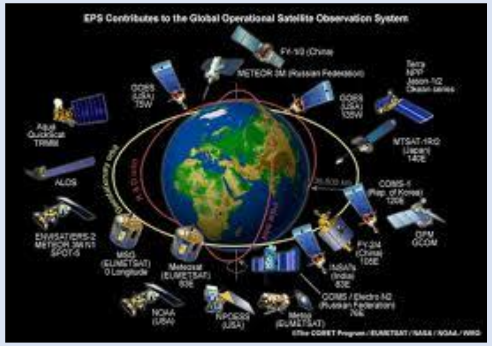
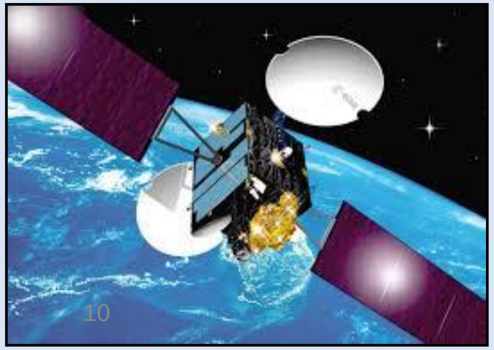
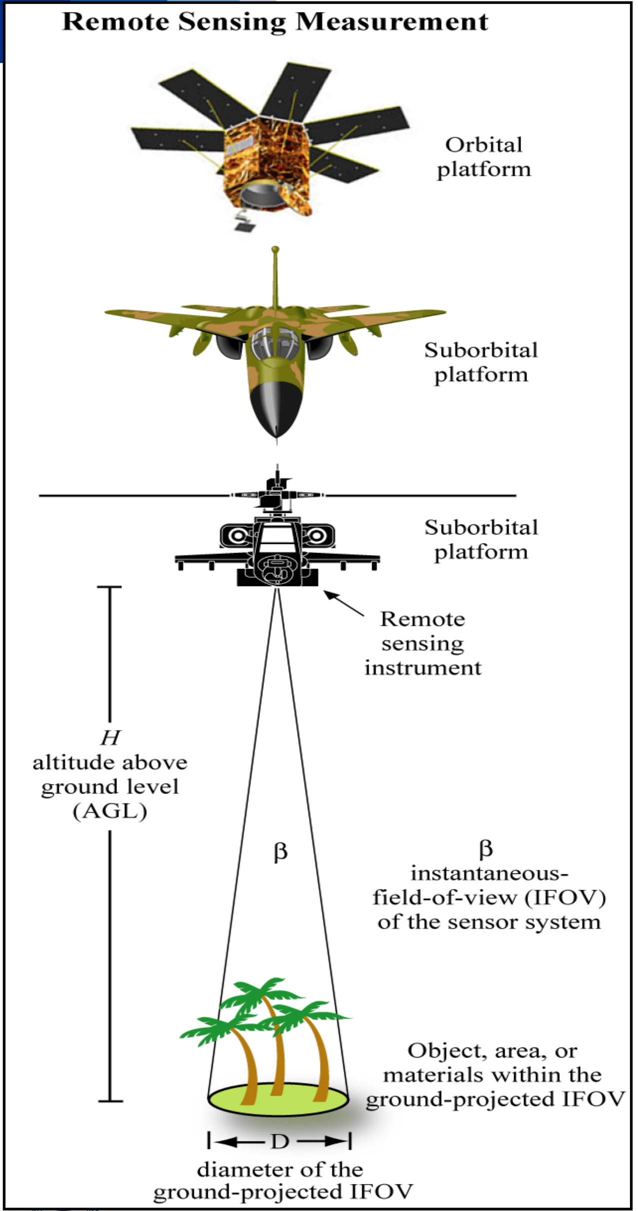




Remote Sensing - basic physics and principles



Introduction

What is remote sensing:

the art, science and technology of

- acquiring,
- processing, and
- interpreting

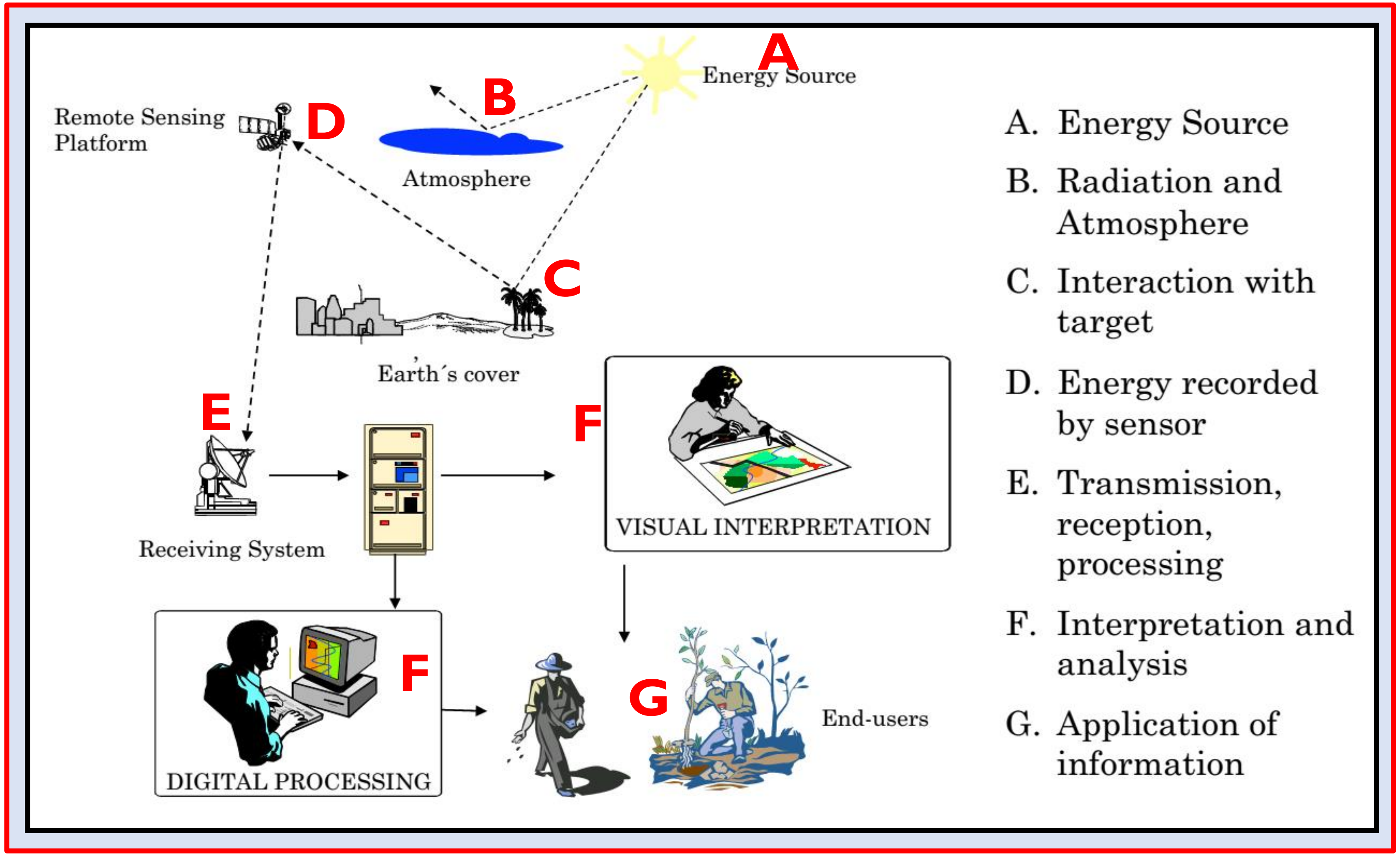
images and related data that are obtained from **ground-based, air-or space-borne instruments** that record the interaction between matter (target) and electromagnetic radiation

Energy patterns derived from **noncontact sensor systems**

Remote Sensing: using electromagnetic spectrum to image the **land, ocean,** and **atmosphere**.

Remote Sensing: Primary components

- Energy- radiation
- Sensor
- Object



Importance of remote sensing

- Observes the distribution of certain surface properties in exquisite **spatial detail**: allows the true spatial structure to be examine
- Captures a **“snapshot”** of the spatial distribution. “Freezes” the continually changing environment
- Offers a **repeated view**: consistent measurements by a single sensor
- Observes part of the earth other methods miss
  - Shipping routes are concentrated in certain zones
  - Ships tend to avoid poor weather hazardous regions
  - Drifting buoys tend to avoid regions of divergent currents

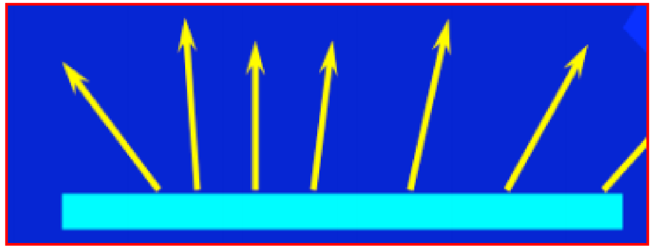
Limitations of remote sensing

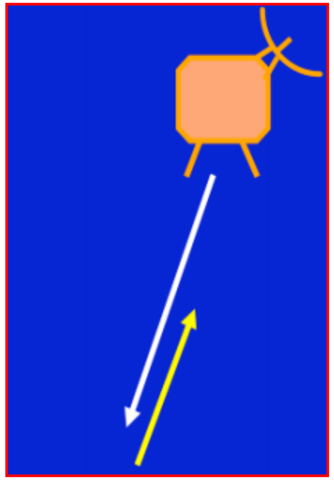
- Can observe only some of the earth's properties and variables
- Measures only at or **near the surface**
  -- Although the surface is the most critical place to measure
- Measurements may be corrupted by the atmosphere
- Some satellites/methods cannot see through clouds at all
- Can make measurements only when the satellite is in the right place at the right time
- All measurements require calibration and validation using in situ data

Sources of energy for remote sensing

- The Sun
  - --- Visible waveband
  - --- Near Infra red waveband

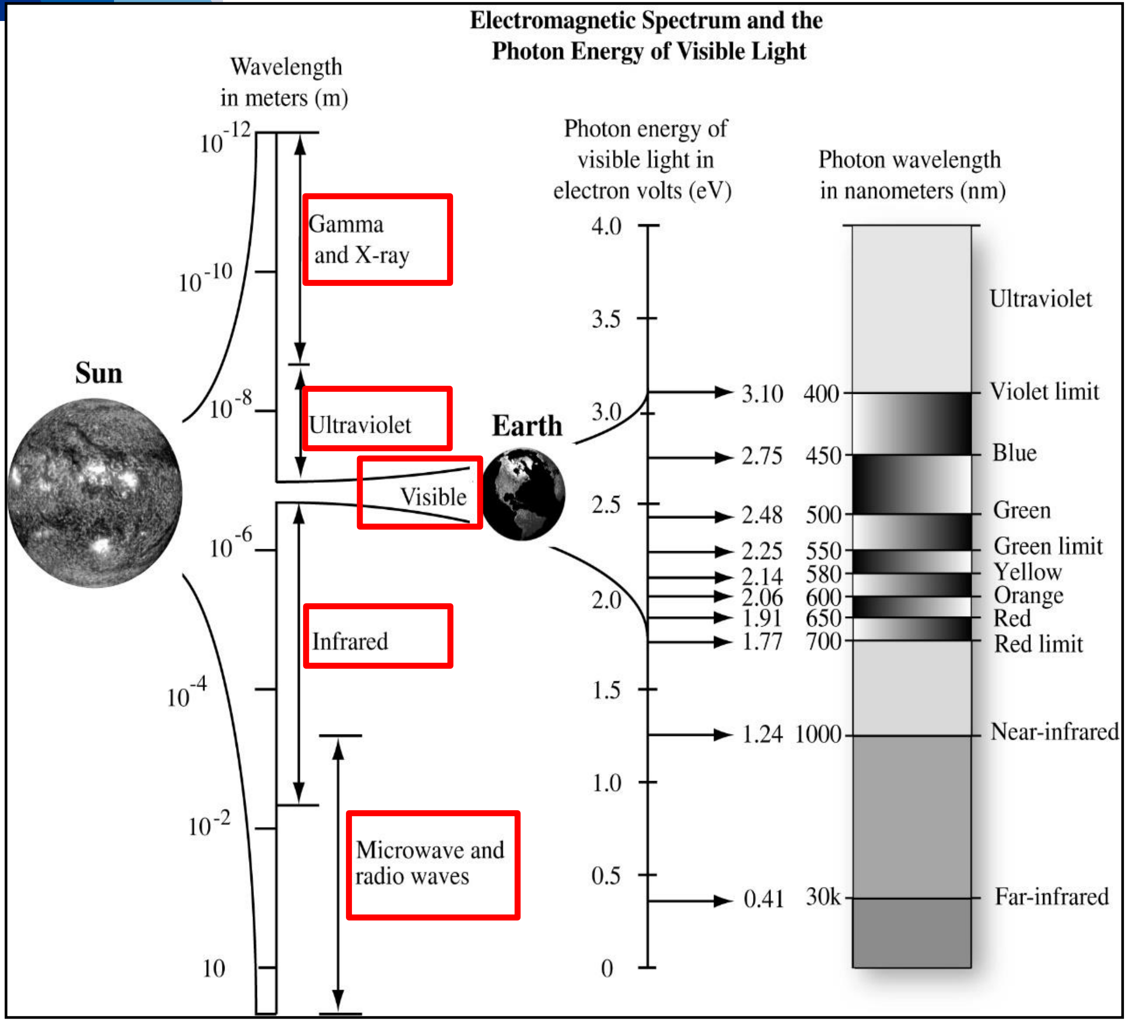
- Thermal emission by the earth surface
  - --- Thermal infra red
  - --- Microwaves

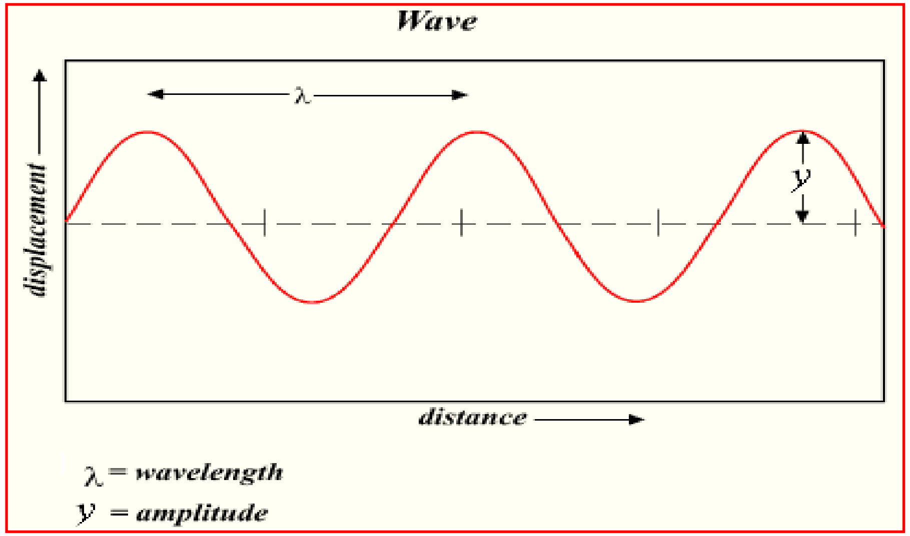




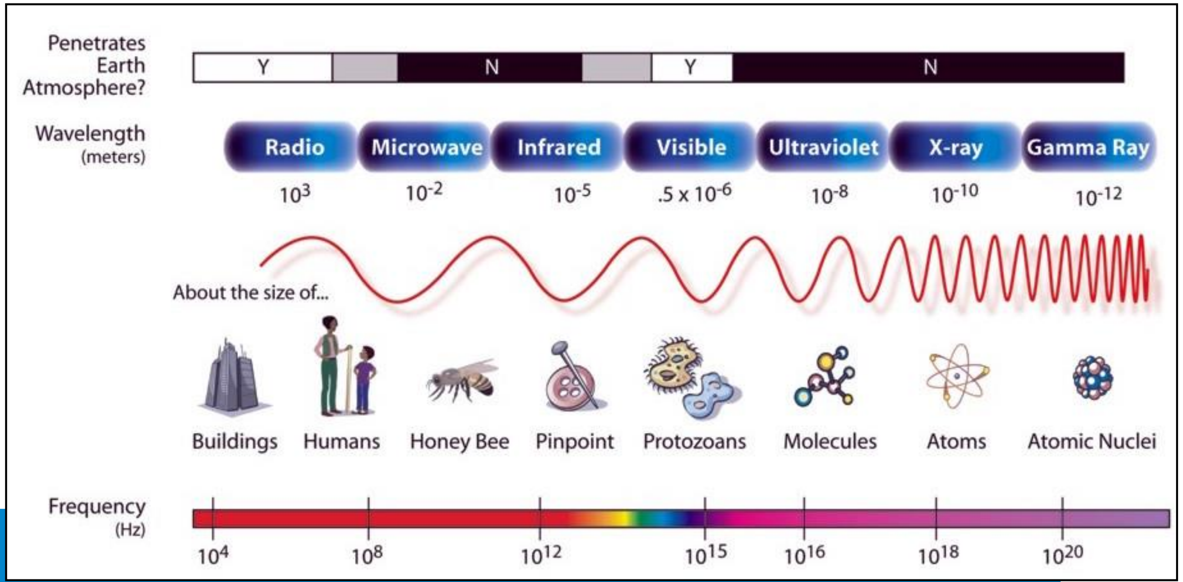
- Energy source on the satellite
  - --- Microwaves (Radar)
  - --- Visible (Lidar)

Electromagnetic Spectrum





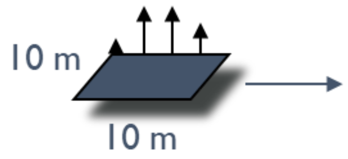
Electromagnetic radiation behaves in most circumstances as waves and can thus be characterized as waves.



The Sun produces a *continuous spectrum* of energy that continually bathe the Earth in energy.

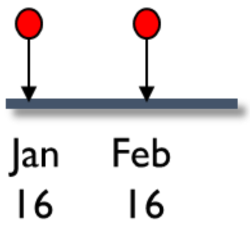
The visible portion of the spectrum may be measured using wavelength (micrometers or nanometers) or electron volts (eV).

Remote Sensor Resolution Considerations

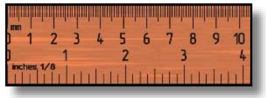


- Spatial - the size of the field-of-view. e.g., 10 × 10 m.

- Spectral - the *number* and *size* of spectral regions (or frequencies) the sensor records data in,
  e.g., blue, green, red, near-infrared, thermal infrared.



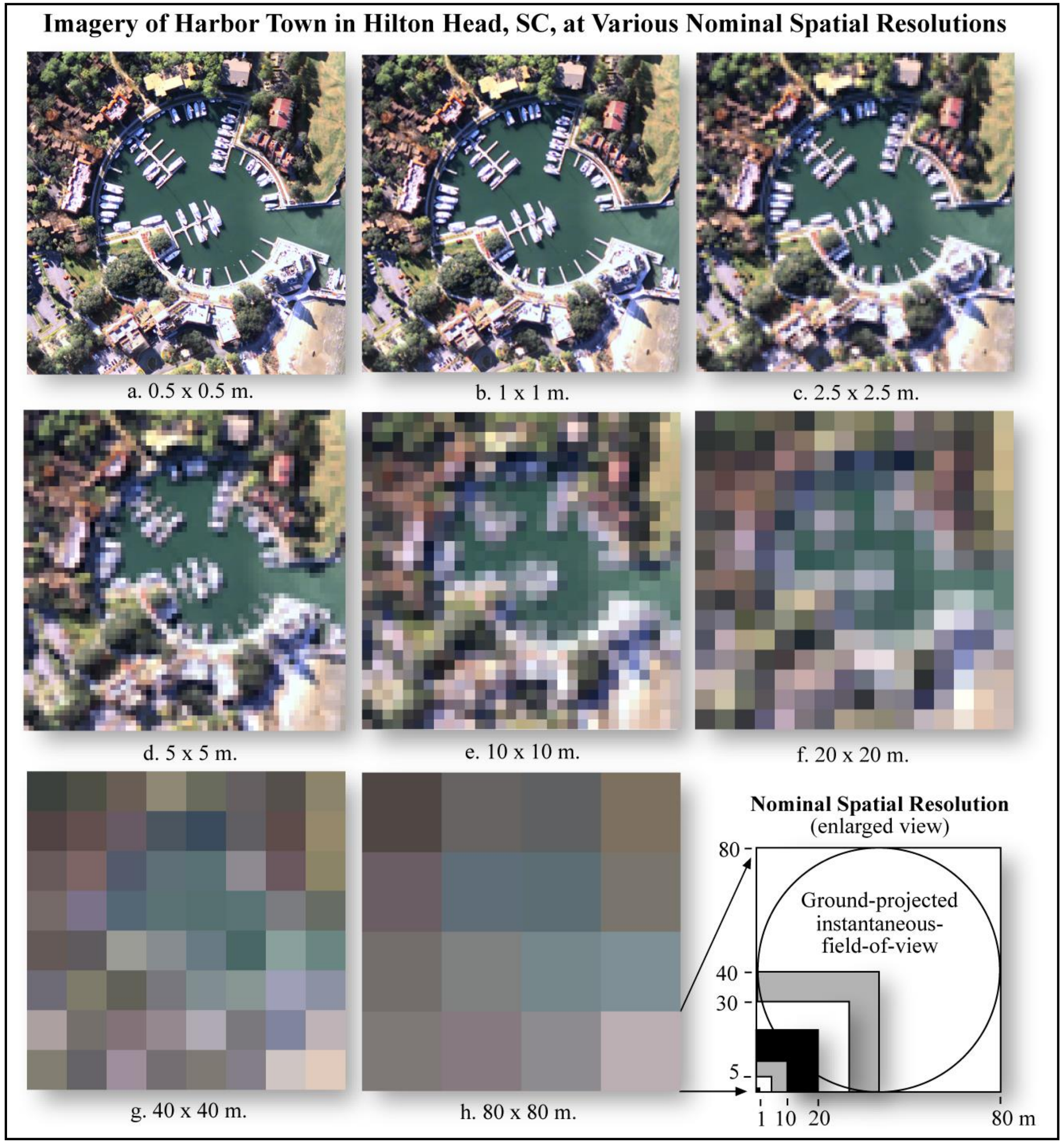
- Temporal - how often the sensor acquires data. e.g., every 30 days.

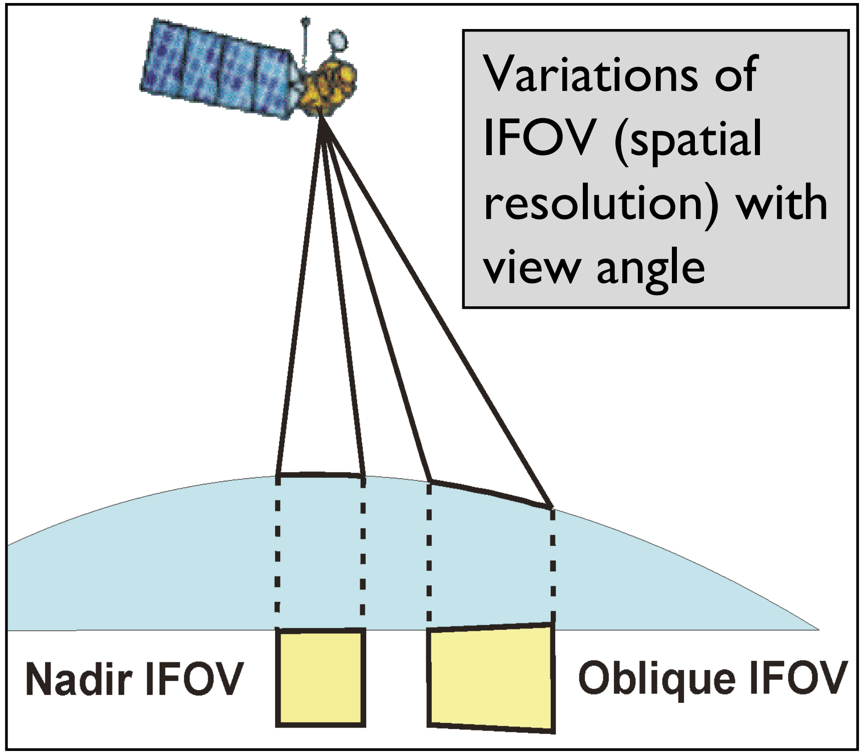


8-bit
(0 - 255)
10-bit
(0 - 1023)

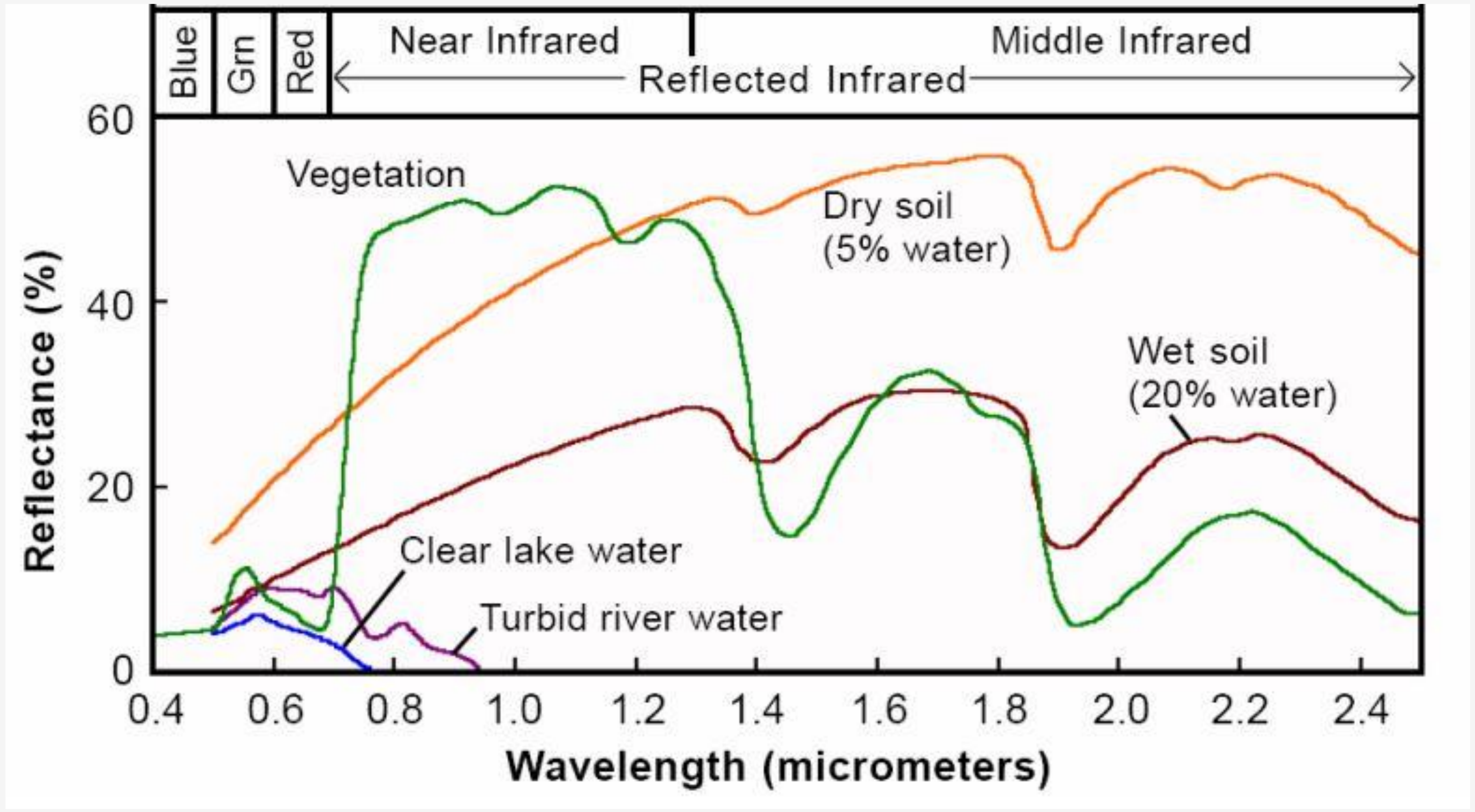
- Radiometric - sensitivity of detectors to small difference in electromagnetic energy.

Spatial Resolution





Spectral signature



Typical spectral signatures of specific land cover types in the VIS and IR region of the electromagnetic spectrum

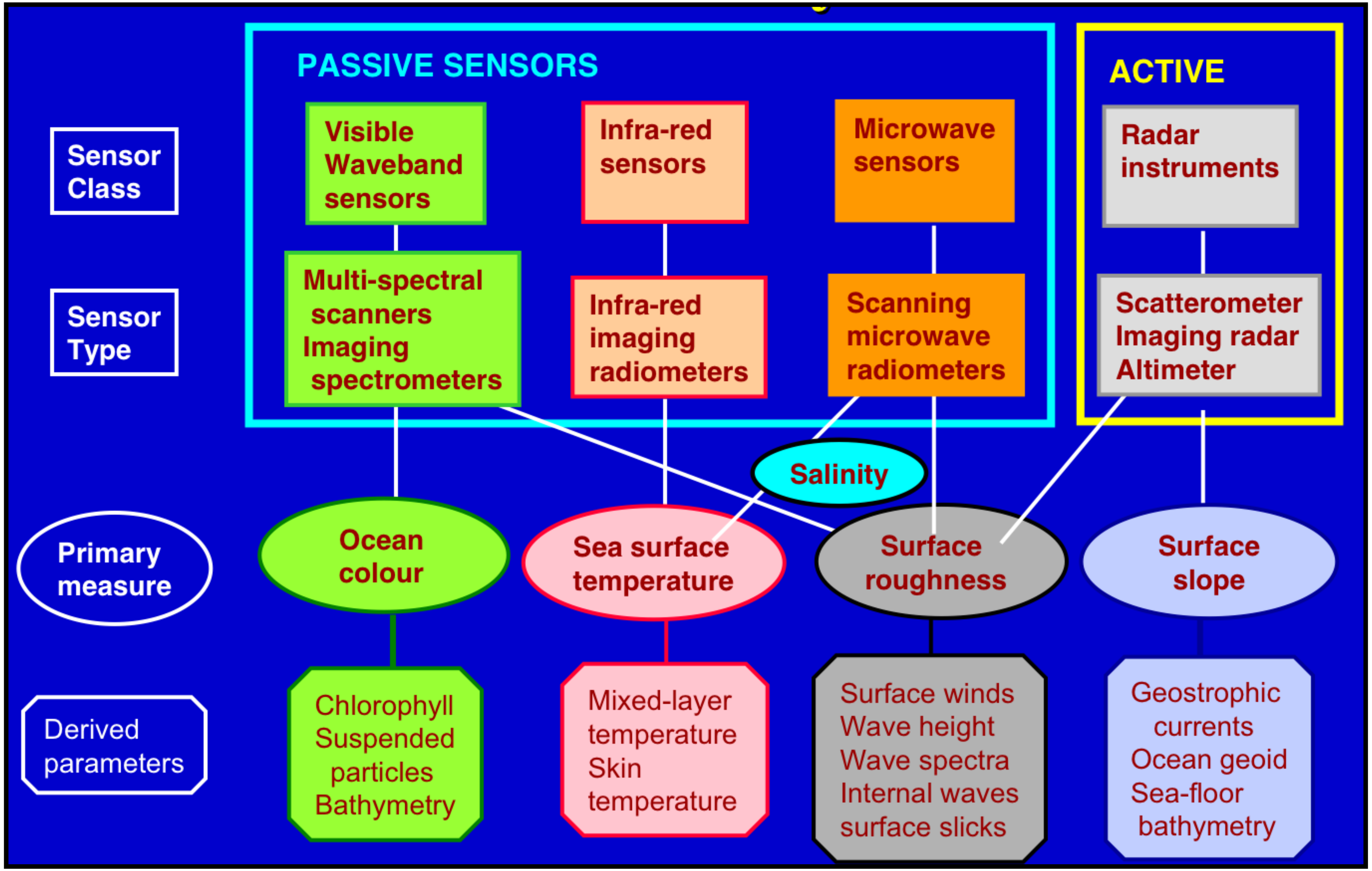
Active and passive sensors

Active sensors (microwave) create their own radiation with which to illuminate the target, and then observe the nature of the reflected signal

Passive (sun, IR and visible wavelength) sensors which rely on naturally occurring radiation.

Passive sensors	**Wavelength**	**Information**
Visible wavelength radiometers	400 nm - 1 μm	Solar radiation reflected by Earth surface
Infrared (IR) radiometers	about 10 μm	Thermal emission of the Earth
Microwave radiometers	1.5 - 300 mm	Thermal emission of the Earth in the microwave
Active devices		
Altimeters	3 - 30 GHz	Earth surface topography
Scatterometers	3 - 30 GHz	Sea surface roughness
Synthetic aperture radars	3 - 30 GHz	Sea surface roughness and movement

A summary of sensor types & what they measure



The benefits of Earth Observations

Provide the

right information,

in the right format,

at the right time,

to the right people,

to make the right decisions.

Remote sensing for decision making

- Less expensive
- Safety, piracy
- Remote sensing and GIS methods will be used to develop indicators of environmental change

Costs and delivery times

Operation	**Costs** (US$/km^2)	**Time** (months)
Purchase of satellite images	0.55	1
Image processing and interpretation	0.16	6
Field survey	0.09	0.5
Fuzzy relational calculus	0.08	4
Database construction-GIS	0.03	5
Map production	0.02	1
Total	**1.3**	**17.5**

Remote sensing for decision making

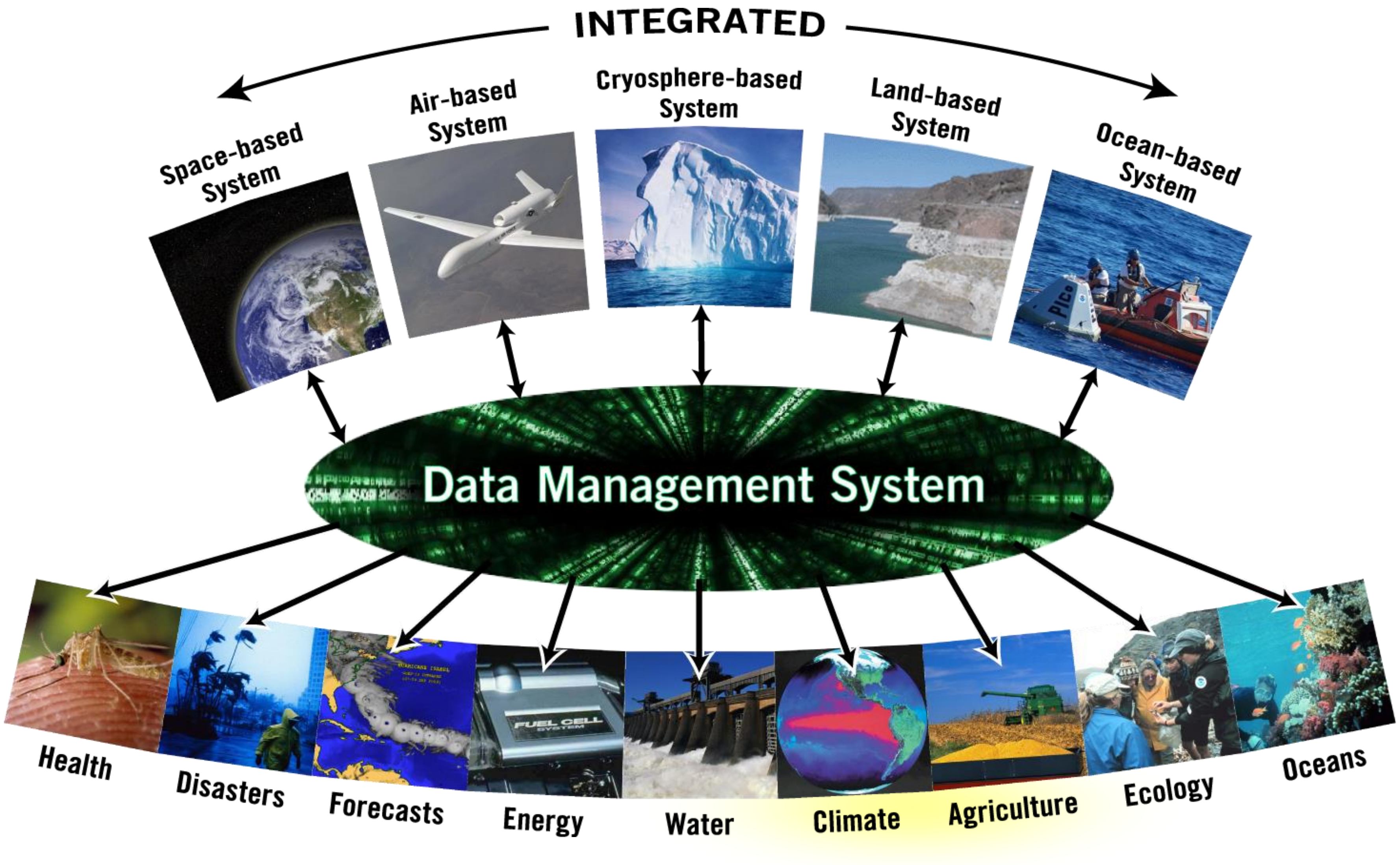
Table 1
Characteristics of different earth observing satellite instruments that have potential use in application development for decision makers at the state/local and tribal level

Satellite	Instrument	Spectral bands (μm)	Spatial resolution	Temporal resolution	Cost[a]
Landsat 7	ETM+	3 Visible 1 NIR 2 SWIR 1 TIR 1 Panchromatic (B&W)	30 m 60 m 15 m	16 days	\$600 per scene
NOAA-K, L, M	AVHRR	1 Visible, 1 NIR, 1 SWIR, 1 MWIR, 2 TIR	All at 1.1 km	Daily	Free
Terra, Aqua	MODIS	1 Visible and 1 NIR 5 Visible, NIR, SWIR 29 Visible, NIR, SWIR, MWIR, TIR	250 m 500 m 1 km	1–2 days	Free
Terra	ASTER	2 Visible 1 NIR 6 SWIR 5 TIR	15 m 15 m 30 m 90 m	16 days	Free
IKONOS	IKONOS	1 Panchromatic (B&W) 3 Visible 1 NIR	1 m 4 m 4 m	3 days	\$10.50/km^2 for archived data (geo)
QuickBird	QuickBird	1 Panchromatic (B&W) 3 Visible 1 NIR	0.61 m 2.4 m 2.4 m	2–6 days	\$18/km^2 for archived data (standard)
GOES	GOES Imager	1 Visible 1 MWIR 1 Thermal 2 Thermal	1 km 4 km 8 km 4 km	30 min	Free
SeaStar	SeaWiFS	6 Visible, 2 NIR	All at 1.1 km	Daily	Free to NASA researchers

Satellites launched by NASA and other US organizations only are shown here. Visible = 0.4–0.7 μm, NIR = 0.7–1.3 μm, SWIR = 1.3–3 μm, MIR = 3–5 μm, LWIR (thermal) = 5–14 μm. Abbreviations: ASTER, Advanced Spaceborne Thermal Emission and Reflection Radiometer; AVHRR, Advanced Very High Resolution Radiometer; ETM+, Enhanced Thematic Mapper+; GOES, Geostationary Operational Environmental Satellite; MODIS, MODerate resolution Imaging Spectroradiometer; SeaWiFS, Sea-viewing Wide Field-of-view Sensor

EO satellites for decision making

Systems and Benefits



…enhance delivery of benefits to society in the following initial areas

Disasters
Reducing loss of life and property from natural and human induced disasters.

Energy
Improving management of energy resources.

Health
Understanding environmental factors affecting human health and well being.

Weather
Improving weather information, forecasting and warning.

Biodiversity
Understanding, monitoring and conserving biodiversity.

Climate
Understanding, predicting, mitigating and adapting to climate variability and change.

Water
Improving water resource management through better understanding of the water cycle.

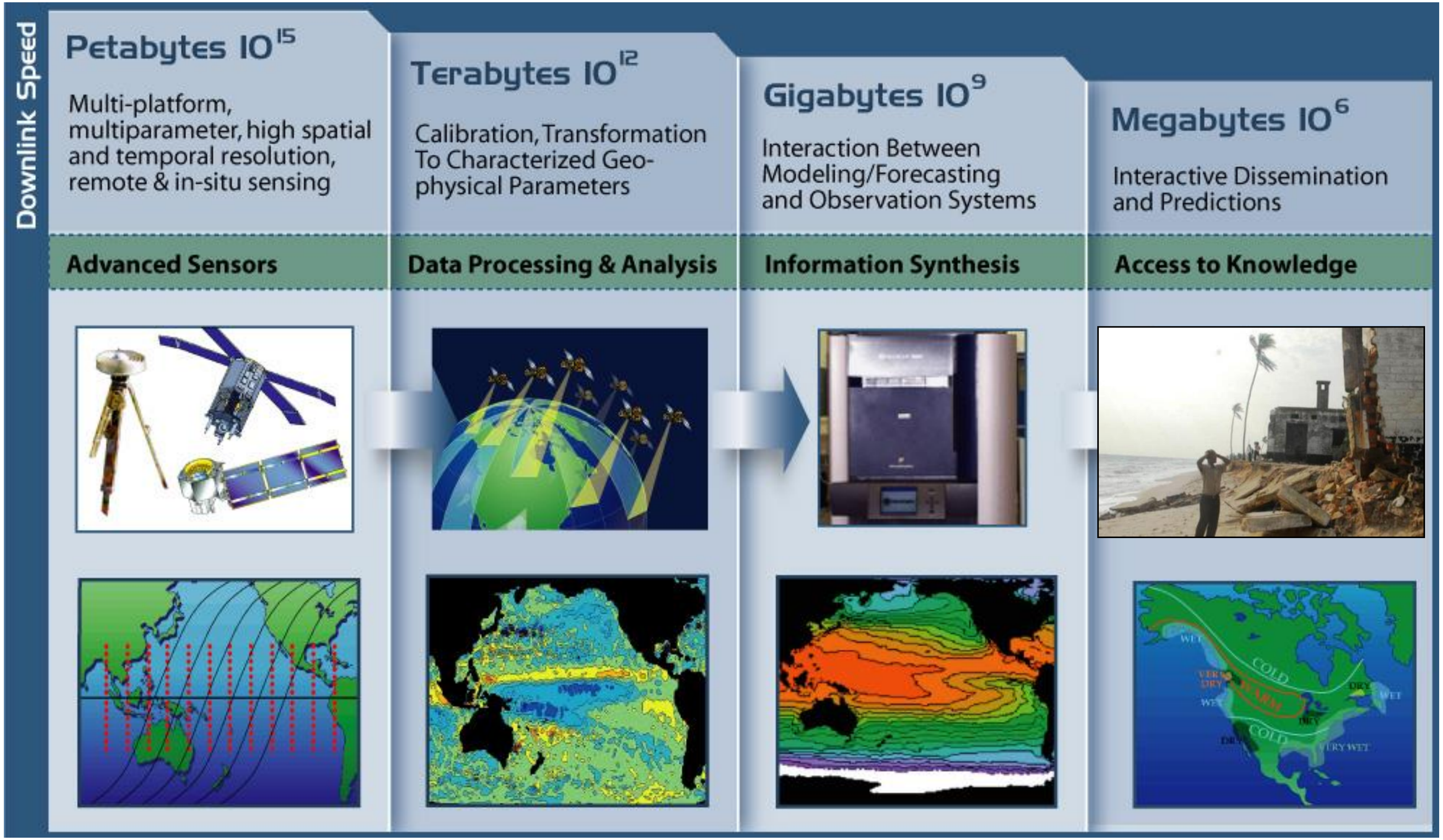
Ecosystems
Improving the management and protection of terrestrial, coastal and marine ecosystems.

Agriculture
Supporting sustainable agriculture and combating desertification.

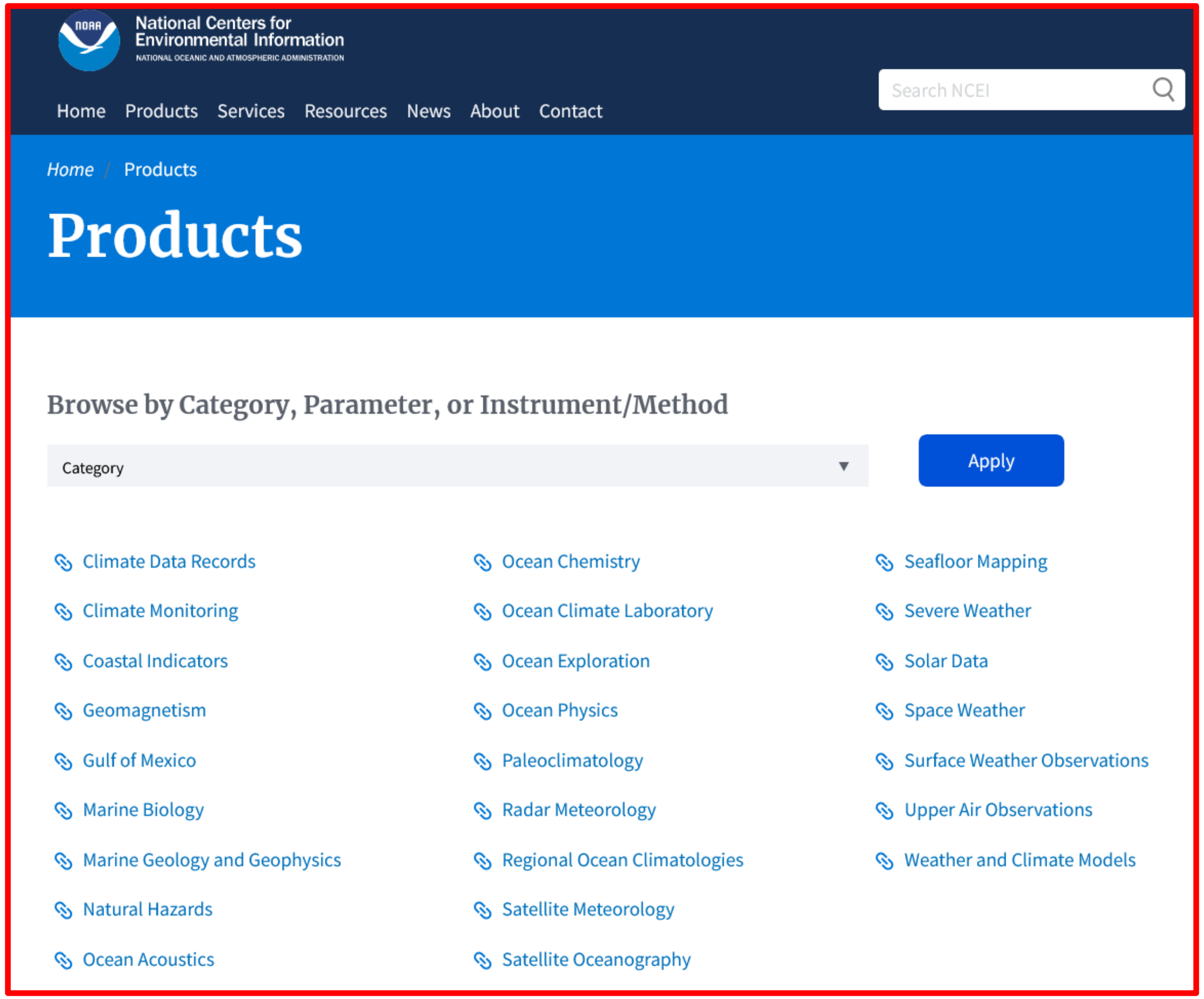
Challenges in creating such a system

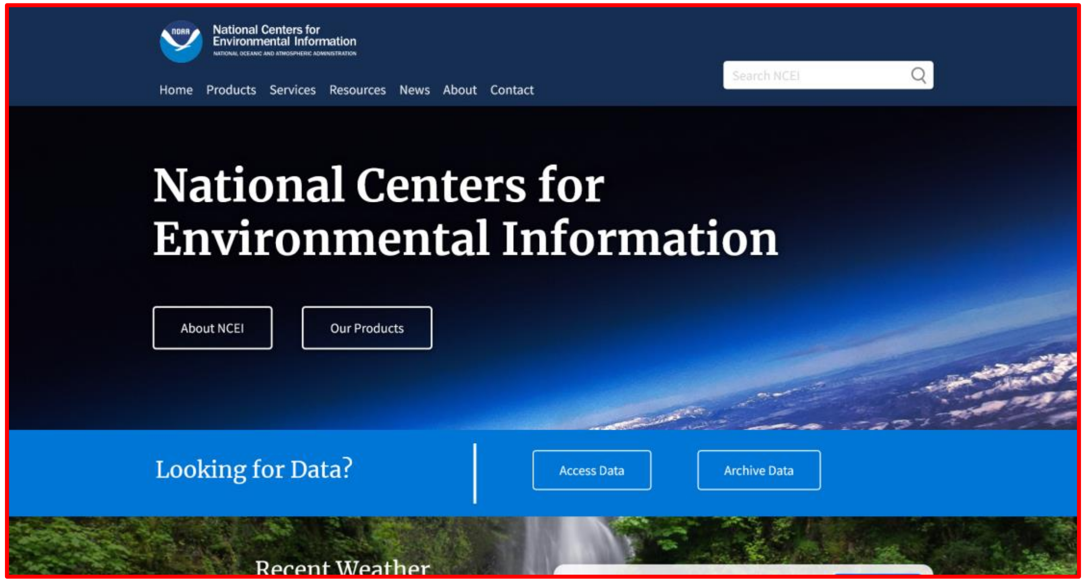
- ***Data policy*** - assuring full and open data exchange and access
- ***Observing scope*** - achieving the needed spatial, temporal and spectral coverage
- ***Data quality*** - producing calibrated data sets in useful formats from multiple sensors and venues
- ***Cost*** - acquiring sufficient resources to deploy observing systems and manage the resulting data and information
- ***Security*** - assuring safe operations and peaceful uses of observing systems
- ***Complexity*** - creating a system equal to the task of delivering useful information about the very complex Earth system

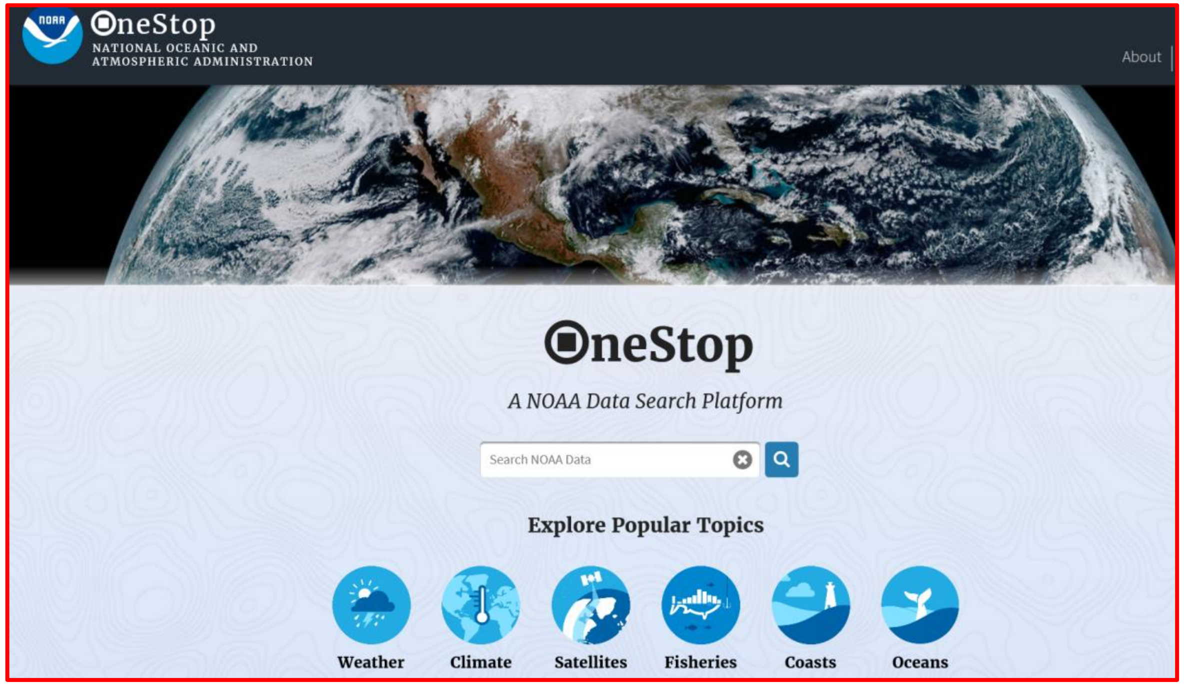
Turning observations into knowledge products



Data Sources







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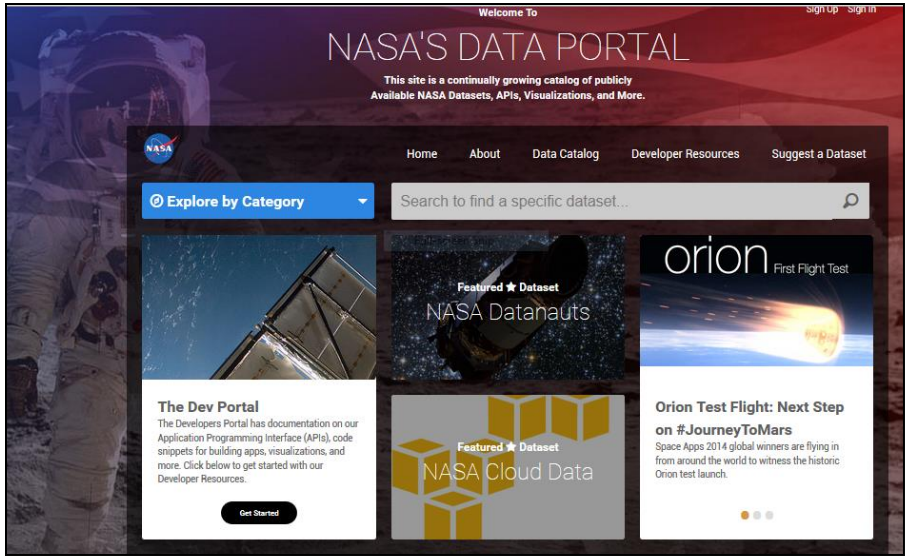

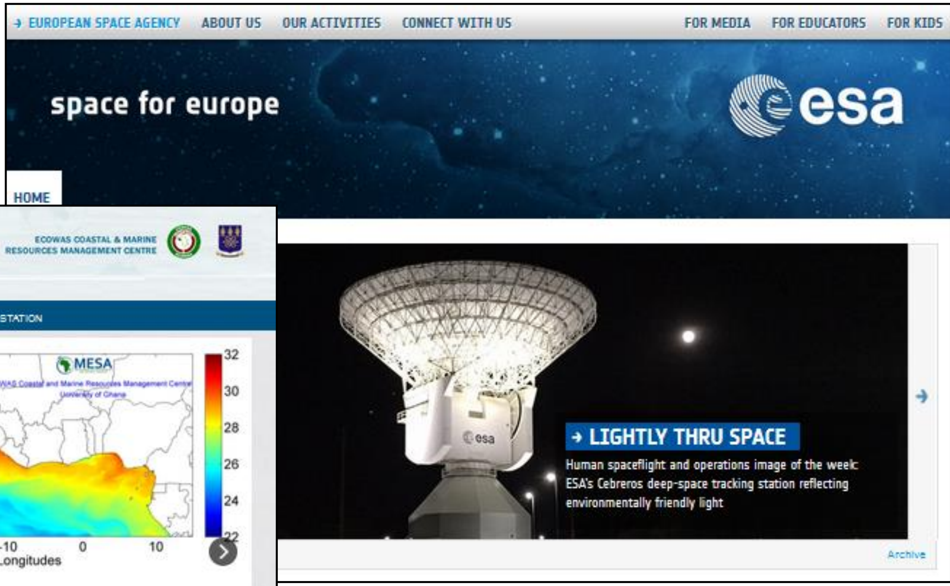

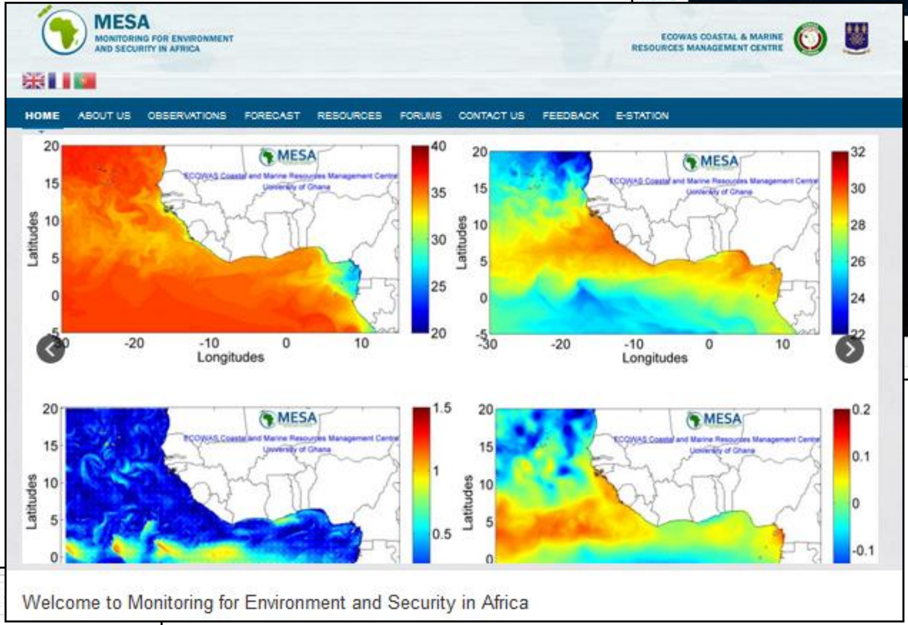

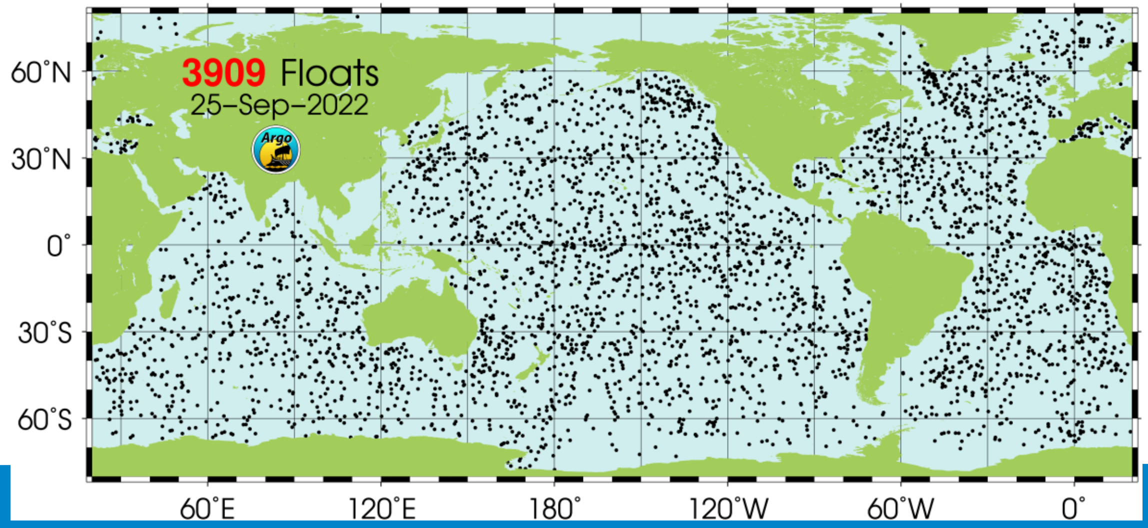

Thank You

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