



Monitoring Water Quality for Aquaculture using NASA Remote Sensing Observations

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Workshop Agenda

Part 1: Presentations [9:30 to 11:00 AM]

- Introduction to NASA Water Resources Program
- Introduction to Earth Observations for Monitoring Water Quality
 - Fundamentals of Remote Sensing
 - Satellite Missions
 - Data Products
- **Demonstration:** data Access, Analysis, and Visualization Web Tools: [Worldview](#)
- Overview of Satellite-based Tool for Rapid Evaluation of Aquatic Environments (STREAM)
- **Demonstration:** data Access, Analysis, and Visualization Web Tools: [STREAM](#)

Break [11:00 to 11:15 AM]

Part 2: Hands-on Exercises [11:15 AM to 12:15 PM]

- Monitoring coastal and inland WQ parameters for facilitating aquaculture applications using Worldview and STREAM

Summary and Survey [12:15 to 12:30 PM]





Part 1: Introduction to Earth Observations for Monitoring Water Quality

Amita Mehta and William Wainwright

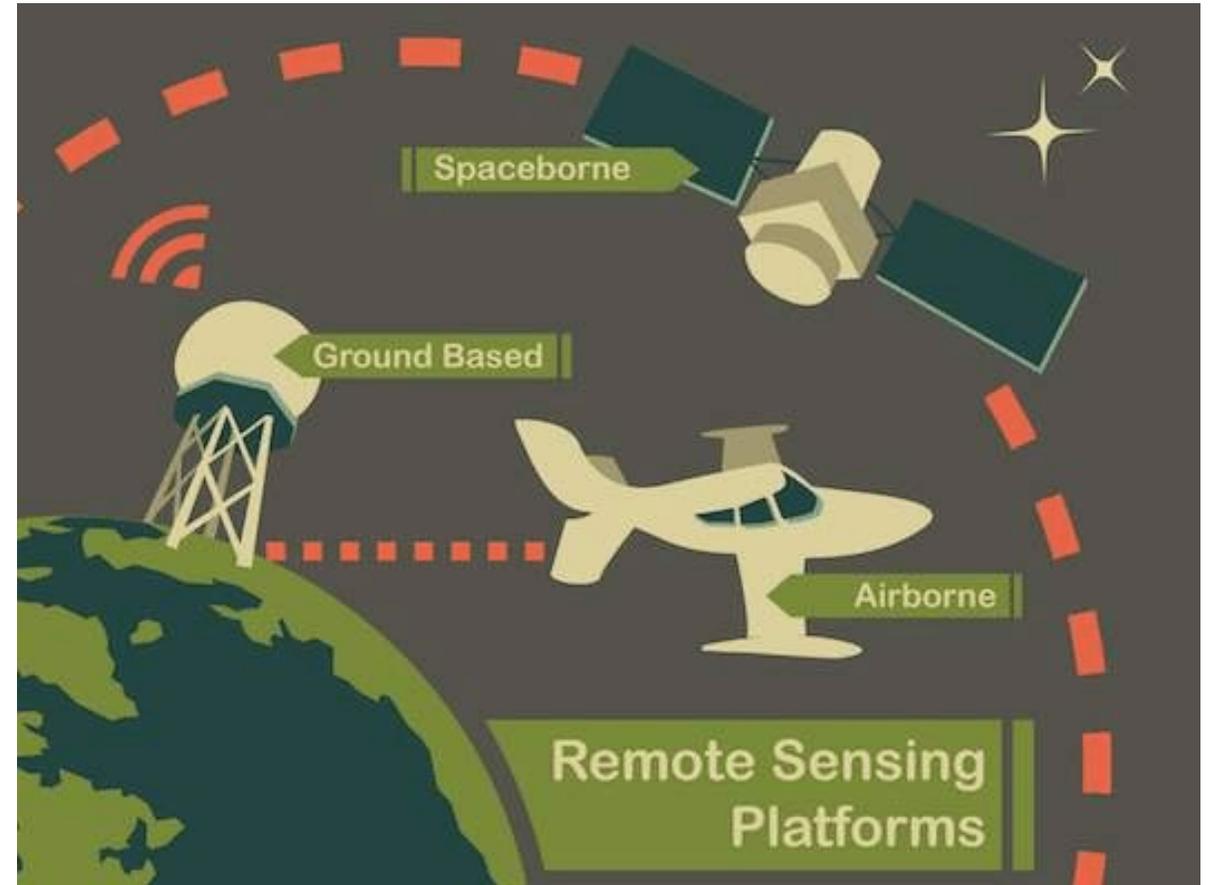


Fundamentals of Remote Sensing

What is Remote Sensing?

- **Remote sensing** is obtaining information about an object from a distance.
- Photography is a very common form of remote sensing.
- There are different ways to collect data, and different sensors are used depending on the application.
- Some methods collect ground-based data, others airborne or spaceborne.

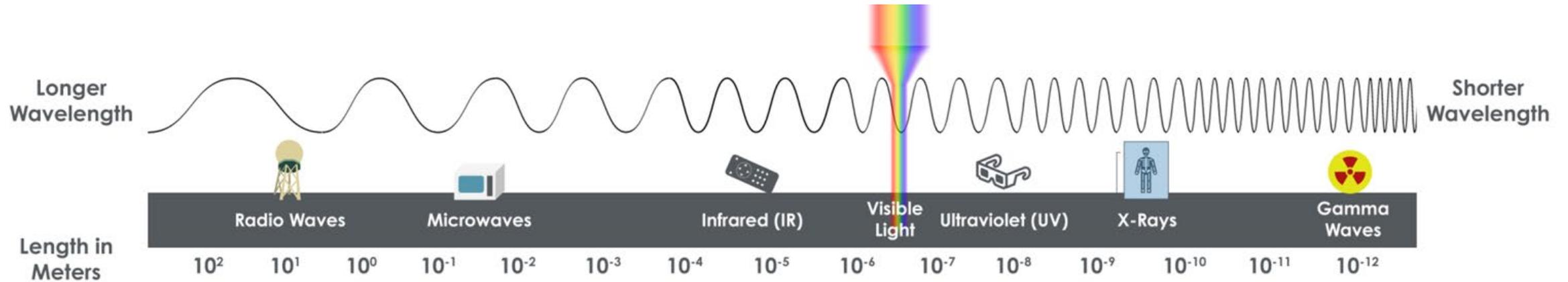
We will focus on spaceborne, satellite-based remote sensing data for monitoring water quality



ARSET – Fundamentals of Remote Sensing



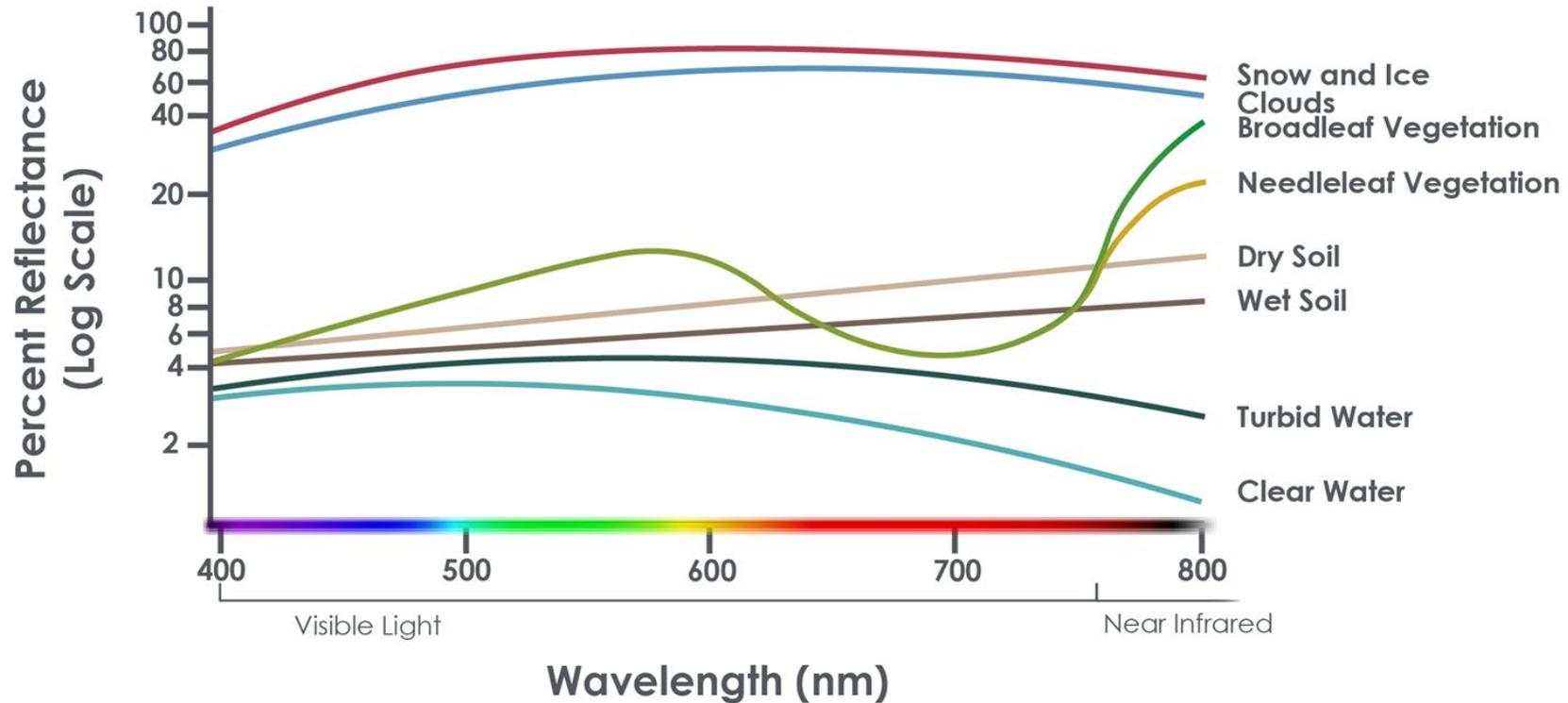
Electromagnetic Spectrum



Materials respond to different wavelengths of light along the **electromagnetic spectrum** through reflection, absorption and emission.



Spectral Signature



How the material reflects, absorbs, or emits radiation at different wavelengths is called the object's **spectral signature**. We can infer what a material is by looking at the kinds of responses it has at different wavelengths.



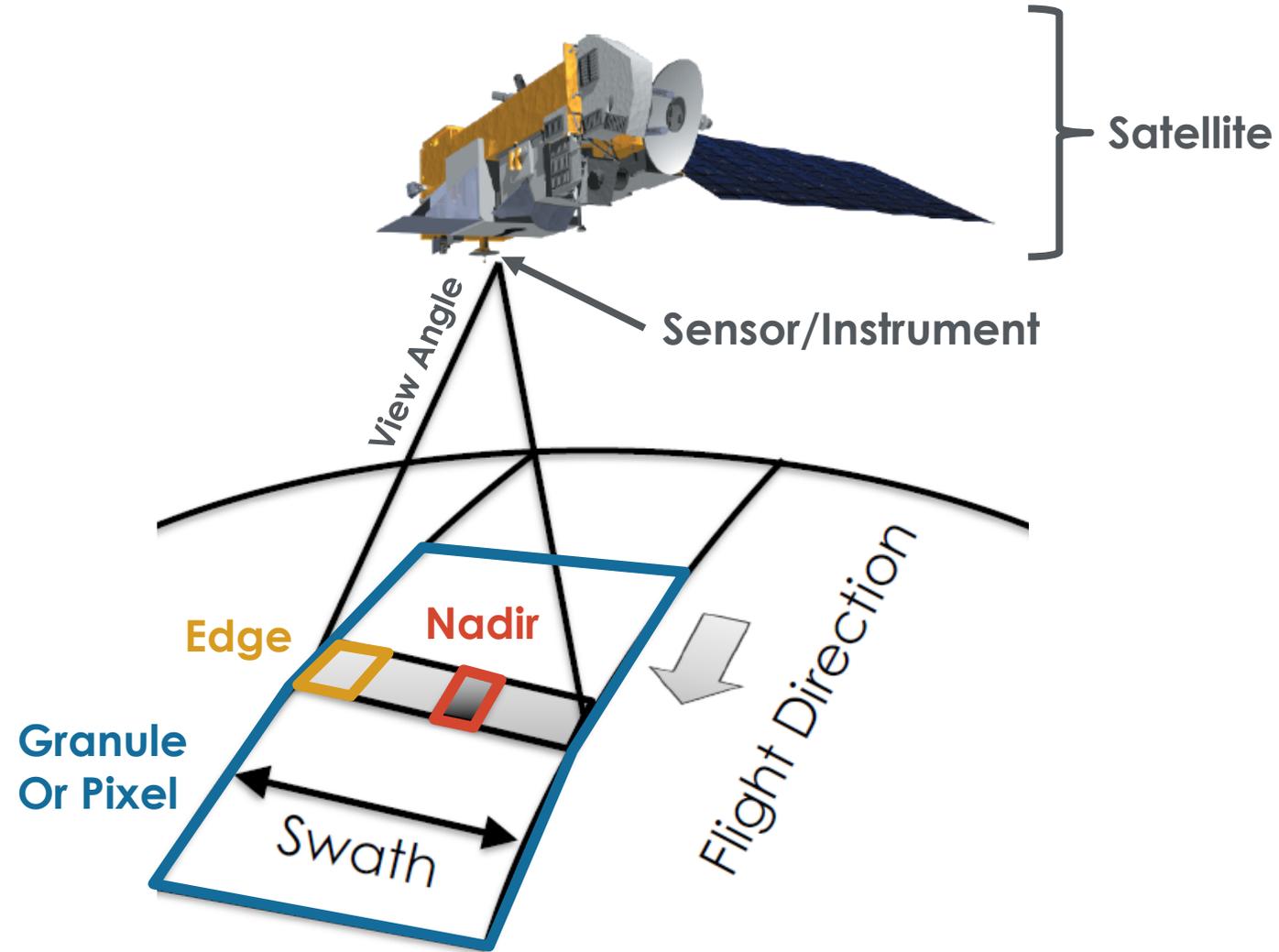
Passive and Active Remote Sensing



- **Passive** sensors measure radiant energy reflected or emitted by the Earth-atmosphere system or changes in gravity from the Earth.
- Radiant energy is converted to **bio-geophysical quantities** such as temperature, precipitation, and soil moisture.
- **Active** sensors provide their own energy source for illumination
- Most active sensors operate in the microwave portion of the electromagnetic spectrum, which makes them able to penetrate the atmosphere under most conditions and can be used day or night.



Satellites and Sensors



Orbits

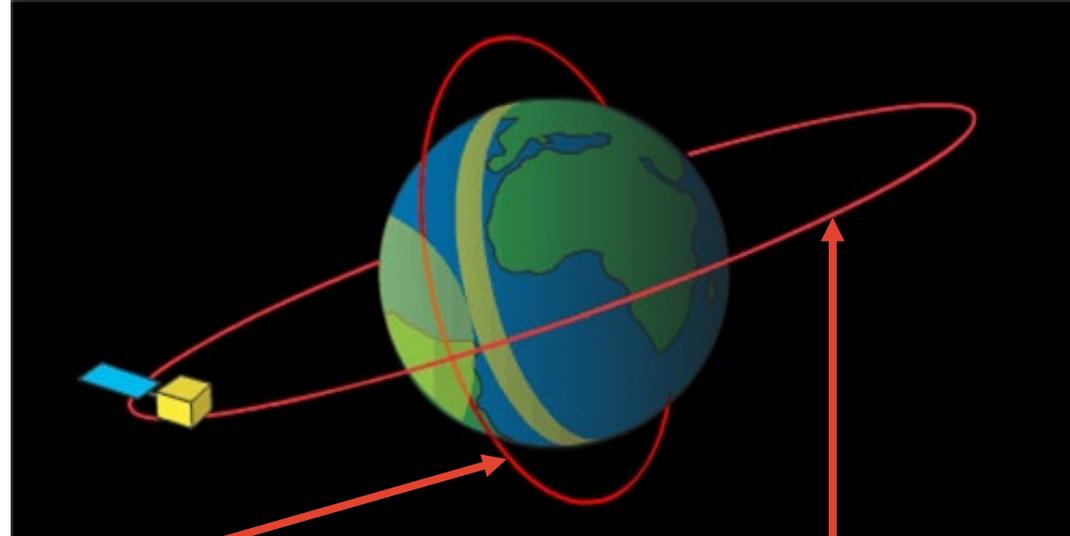


Image Credit: scijinks.gov/orbit

Low Earth Orbit (LEO)

- Polar orbits are common; inclined orbits also have specific uses
- Less frequent measurements
- Global (or near-global) spatial coverage over multiple orbits

Geostationary Orbit (GEO)

- ~36,000 km over the equator with the same rotation period as Earth
- Multiple observations/day possible
- Limited spatial coverage; observations are always of the same area

Orbit impacts temporal resolution and spatial coverage.



Spatial Resolution

- **Spatial Resolution** signifies the ground surface area that forms one pixel in the image. Typically refers to the nadir resolution directly below the instrument.

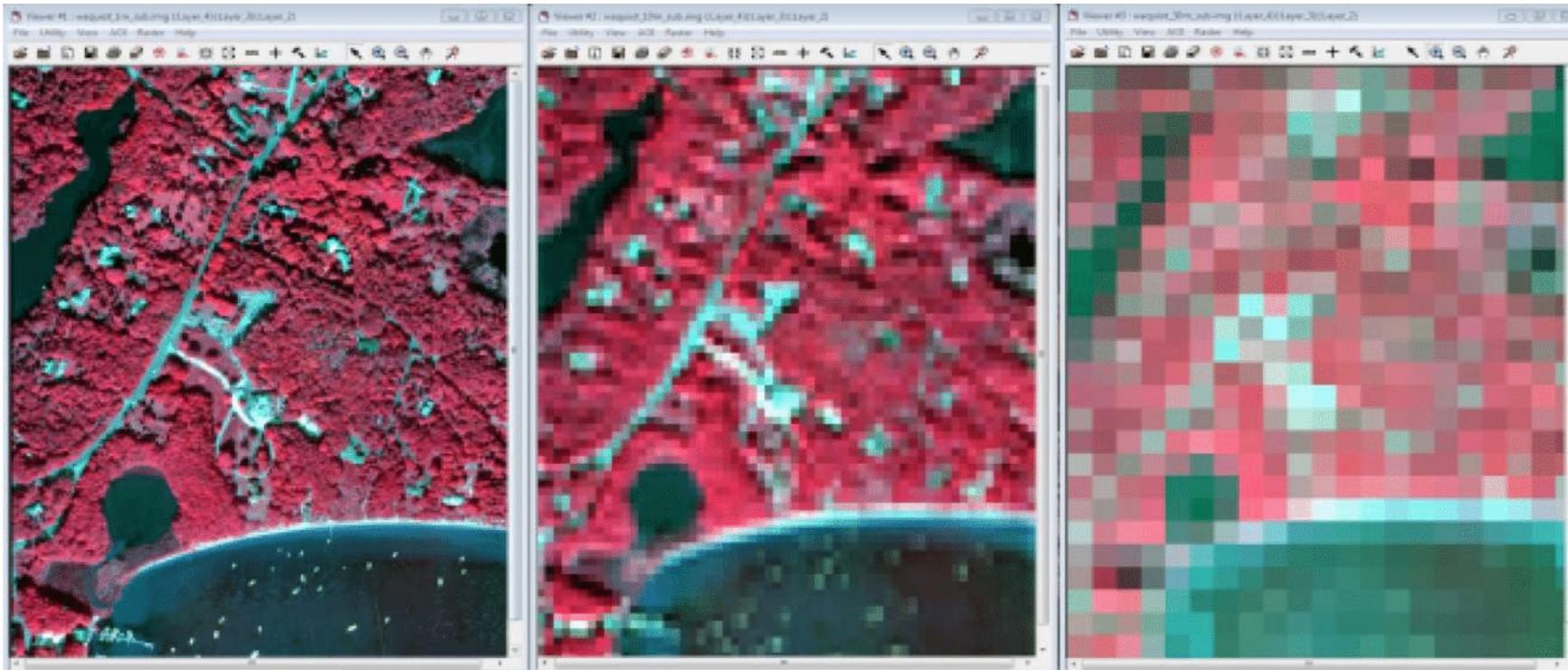
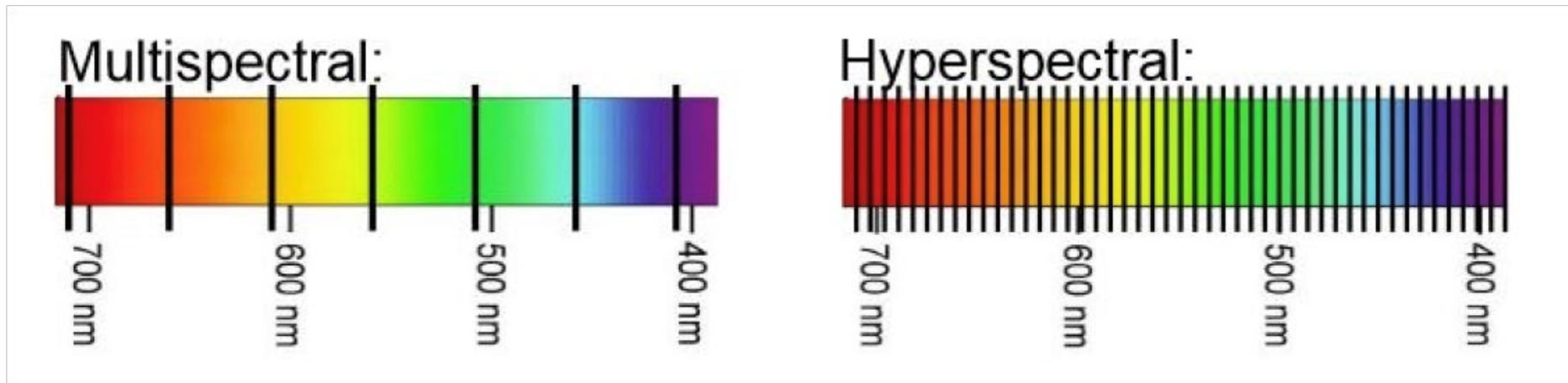


Image Credit: csc.noaa.gov



Spectral & Radiometric Resolution

- **Spectral Resolution** signifies the number and width of spectral bands of the sensor. The higher the spectral resolution, the narrower the wavelength range for a band; think of it as the size of an array of numbers.



- **Radiometric Resolution** describes a sensor's ability to discriminate differences in energy (or radiance); think of it as more precision or “bits” for each number.
- More and finer spectral bands and radiometric resolution provide more detailed data, capable of representing different kinds of bio-geophysical properties.



Satellite Data Processing Levels

- **Level 0 & 1** is the raw instrument data that may be time-referenced. It is the most difficult to use.
- **Level 2** is Level 1 data that has been converted into a bio-geophysical quantity through a computer algorithm (known as retrieval). These data are geo-referenced and calibrated.
- **Level 3** is Level 2 data that have been mapped on a uniform space-time grid and quality controlled.
- **Level 4** is Level 3 data that have been combined with models or other instrument data to fill gaps and gain additional insight.
- **Level 3 & 4 data are the easiest to use.**

MODIS Level-3 Sea Surface Temperature

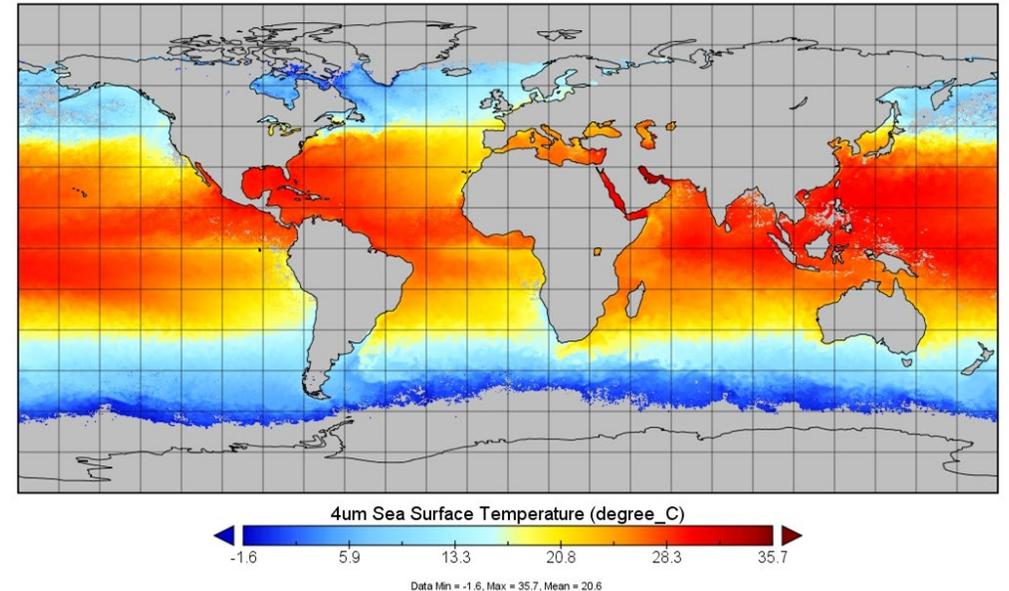


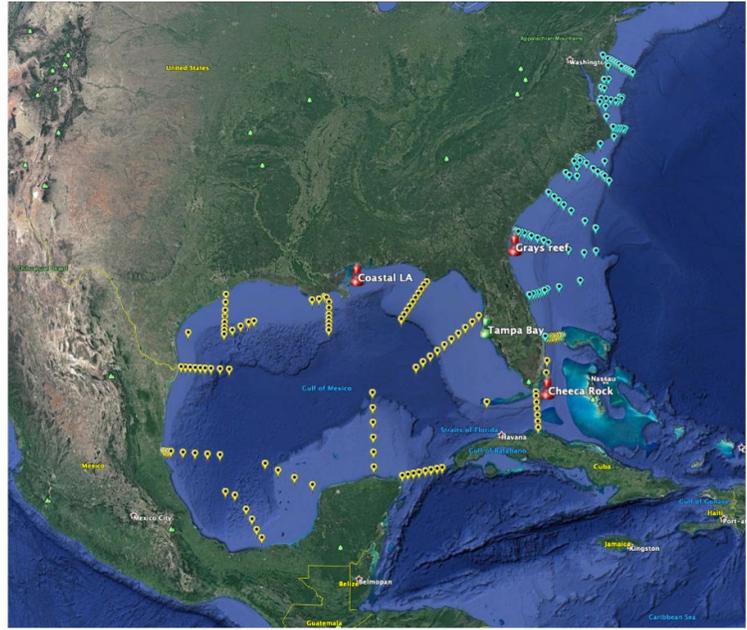
Image Credit: [NASA JPL PODAAC](#)



Why Monitor Water Quality Using Remote Sensing?

In Situ

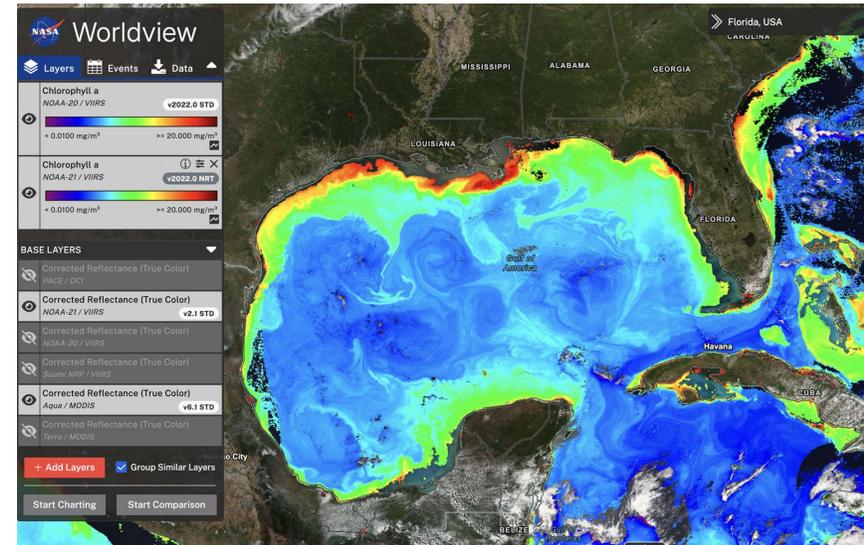
- Limited spatial and temporal coverage
- Expensive



Buoy Locations

Remote Sensing

- **More cost-effective**, with **improved spatial and temporal coverage**
- Provides information where there are no ground-based measurements
- Data are **freely available** with web tools and trainings



Chlorophyll-a Concentration (NOAA-21 VIIRS)
13 April 20205



Limitations of Remote Sensing

- Spectral, spatial, temporal, and radiometric resolution are **competing priorities**; tradeoffs must be made.
- **Interference** from clouds, sun glint, and other sources can cause missing data.
- **Algorithms** to derive water quality parameters **are complex**.
- **Large amounts of data** in a variety of formats can require specialized processing and visualization tools.
- While the data are generally validated with selected surface measurements, **local assessment is recommended** to ensure that the data are relevant for any particular use case.



Image Credit: NOAA





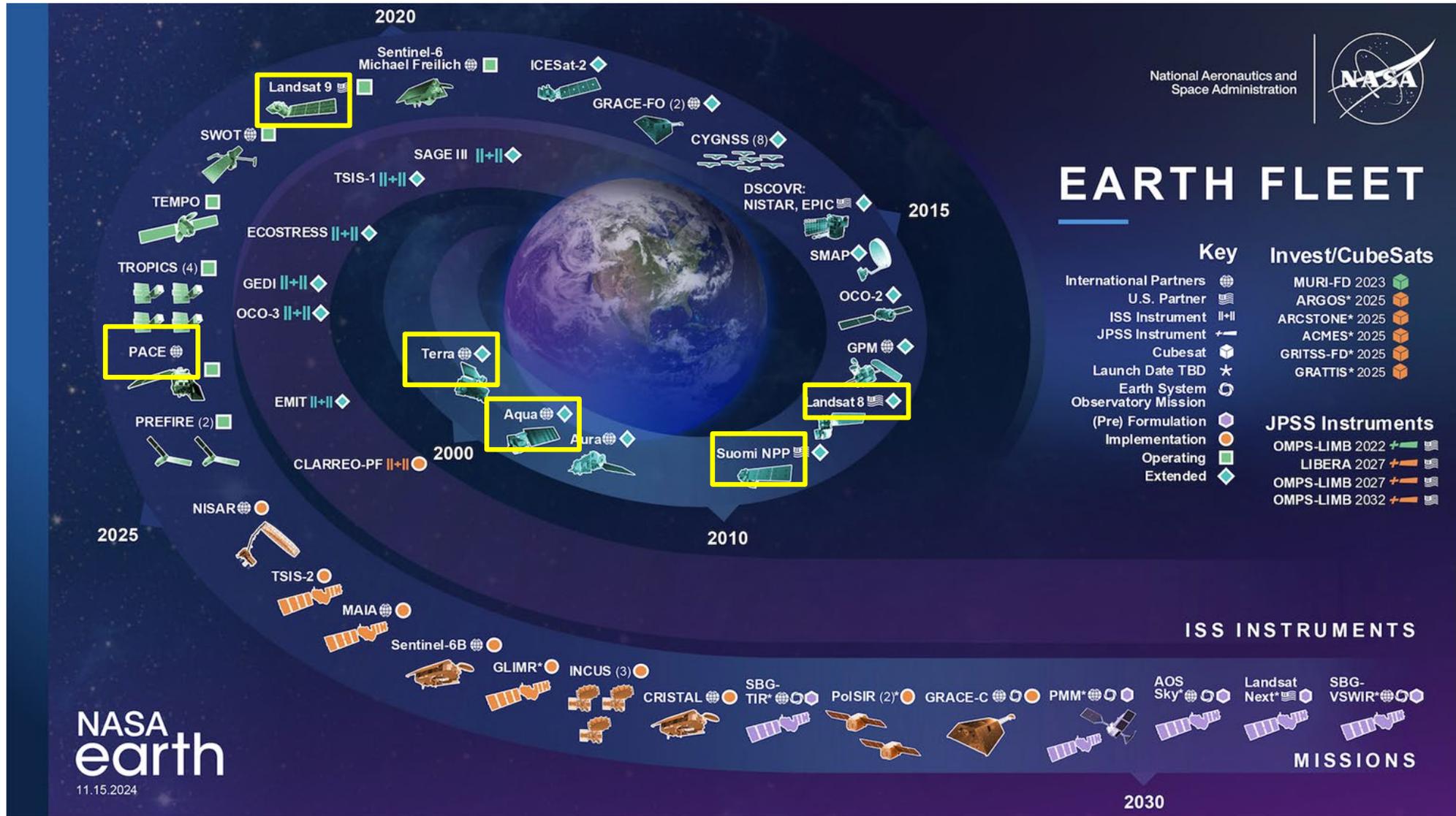
Satellite Missions and Data Products

Relevant Water Quality Parameters for Aquaculture

- Chlorophyll/Harmful Algal Bloom (Chl-a)
- Sea Surface Temperature (SST)
- Total Suspended Solids (TSS)
- Colored Dissolved Organic Matter (CDOM)
- Salinity
- Bathymetry
- Water Surface Height
- Dissolved Oxygen
- Nutrients
- pH



NASA's Earth Observing Satellites



Water Quality Parameters Observed from Satellites

- Chlorophyll/Harmful Algal Bloom (Chl-a)
- Sea Surface Temperature (SST)
- Total Suspended Solids (TSS)
- Colored Dissolved Organic Matter (CDOM)
- Salinity
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Selected Water Quality Parameters from Satellites



Sediment Plume Off the Coast of Florida Image captured on Sep 30, 2022 by the MODIS instrument aboard NASA's Aqua satellite

Parameters	Satellites
Chl-a, TSS, Secchi Disk Depth	Landsat 8 Landsat 9
Chl-a, SST,	Terra Aqua
Chl-a, SST	SNPP JPSS
Chl-a, TSS, Secchi Disk Depth	Sentinel 2A Sentinel 2B & 2C
Chl-a	Sentinel 3A & 3B
Chl-a	PACE
Salinity	SMAP
Bathymetry	ICESat-2
Water Surface Height	Jason-3, Sentinel-6



Satellites and Sensors for Water Quality Monitoring

Satellites Orbits	Sensors	Spectral Measurements	Temporal Coverage, Observation Time, and Resolution	Spatial Coverage and Resolution
Landsat 8 Landsat 9 polar	TIRS, OLI TIRS-2, OLI-2	Visible, Near IR, Middle IR, Thermal IR	2/2013 – Present 11/2021– Present 10:30 am/pm local time 16 Day	Global Swath: 136 km 30 m
Terra Aqua Polar	MODIS	Visible, Near IR, Middle IR, Thermal IR	12/1999 – Present (10:30 am/pm) 4/2002 – Present (13:30 am/pm) 1-2 Days	Global Swath: 2330 km 250 m to 1 km
SNPP JPSS polar	VIIRS	Visible, Near IR, Middle IR, Thermal IR	10/28 2011– Present 11/18 2017 – Present 11/10 2022 – Present 1:30 am/pm local time 12 Hours	Global Swath: 3040 km 375 m, 750 m
Sentinel 2A Sentinel 2B & 2C Polar	MSI	Visible, Near IR	6/23/2025 – Present 3/7/2017– Present 10:30 am/pm 5 Day	Global Swath: 290 km 10 m, 20 m, 30 m
Sentinel 3A & 3B Polar	OLCI	Visible, Near IR	2/16/2016-Presenet 4/25/2018-Present 10 am/pm, 1 to 2 Days	Global Swath: 1270 km 300 m
PACE Polar	OCI	Visible, Near IR, Shortwave IR	2/8/2024 –Present 1 AM/PM 1 to 2 Days	Global Swath: ~2500 km 1 km

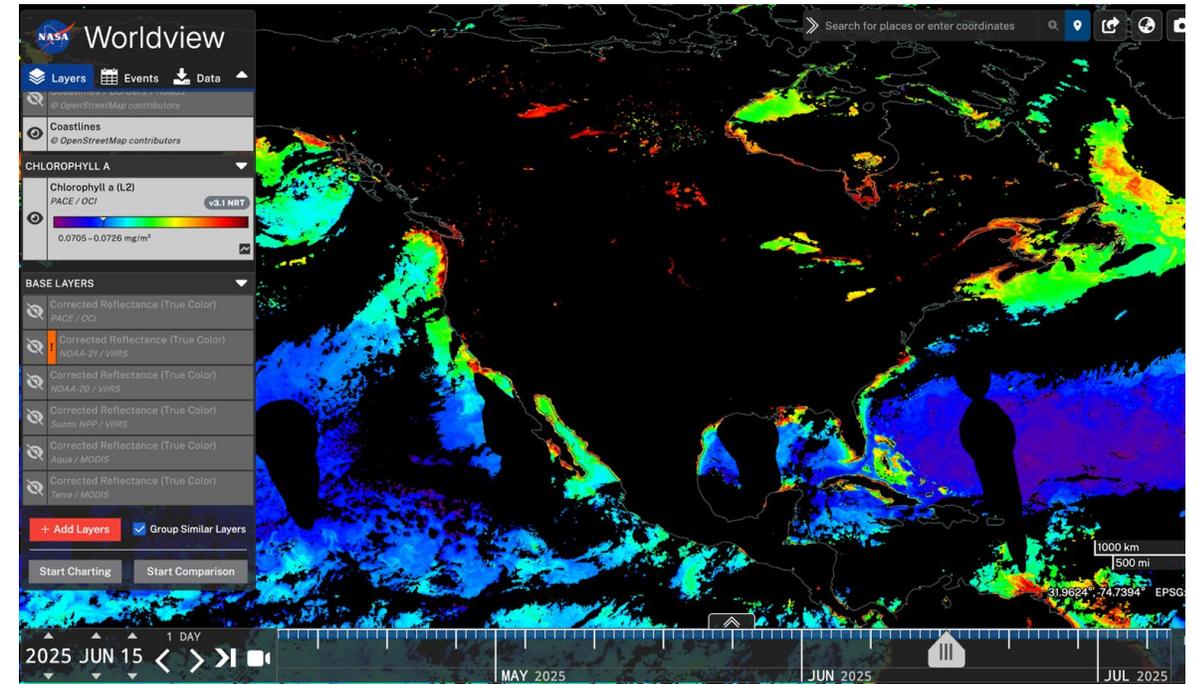
Satellites and Sensors Relevant for Water Quality Monitoring

Satellites Orbits	Sensors	Spectral Measurements	Temporal Coverage, Observation Time, and Resolution	Spatial Coverage and Resolution
SMAP Polar	Radiometer	Microwave (L-band)	1/2015-Present 6:00 am/pm local time 2-3 Days	Global Swath: 1000 km 36 km
ICESat-2 Near-polar	ATLAS Laser Altimeter	Visible	9/2018 – Present 91 Days	Global 3 pairs of Laser Beams, each with 11-17 m footprint Across track spacing 90 m within beams and 3 km between beams
Jason-3 near-Polar Orbit Non-sun synchronous	Radar Altimeter Microwave Radiometer	Poseidon-3B : Ku Band & C Band	1/2016 - Present 9.9 day revisit time Varying local time of observations	Global 30 km along track Swath: 120 km
Sentinel-6/ Michael Freilich Near-polar Orbit Non-sun synchronous	Radar Altimeter Microwave Radiometer	Poseidon-4 : Ku Band & C Band	11/2020 - Present 9.9 day revisit time Varying local time of observations	Global 300 m along track Swath: 14 km

Existing Water Quality Training and Application

Selected ARSET trainings relevant to remote sensing of water quality:

- [NASA Satellite Laser Altimetry for Coastal and Near-shore Bathymetry](#)
- [Introduction to PACE Hyperspectral Observations for Water Quality Monitoring](#)
- [Monitoring Water Quality of Inland Lakes using Remote Sensing](#)
- [Monitoring Coastal and Estuarine Water Quality: Transitioning from MODIS to VIIRS](#)
- [Monitoring Coastal and Estuarine Water Quality Using Remote Sensing and In Situ Data](#)



Chlorophyll-a concentration from PACE-OCI ([NASA Worldview](#))





Data Access, Analysis, and Visualization Web Tool Demonstration: NASA Worldview