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EARTH AND ITS RESOURCES
Published: 14 March 2022
doi: 10.3389/frym.2022.619716

KEEPING AN EYE ON WATER QUALITY FROM THE SKY

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You can learn a lot about rivers, lakes, estuaries, and oceans by looking down at them from the sky. Scientists use a technique called remote sensing to measure the amount of light or heat energy reflected and emitted from the Earth. Sensors can be on satellites or mounted on airplanes, helicopters, or drones. Scientists use this information to map the quality of water in the San Francisco Bay-Delta estuary. Remote sensing helps scientists see where and when there might be problems for human health or for the plants and animals living in the estuary.

WHAT IS WATER QUALITY AND WHY IS IT IMPORTANT?

Water quality is important for humans and the environment. Water quality tells us how good or bad water is for swimming in or for drinking. Farmers need clean water to grow food and raise farm animals. Wildlife and fish also need good water quality [1, 2].

Poor water quality is often caused by pollution and can create health risks for humans, plants, and animals. Monitoring water quality helps

WATER QUALITY

A measure of the condition of water and how clean it is for plants and animals, including humans.

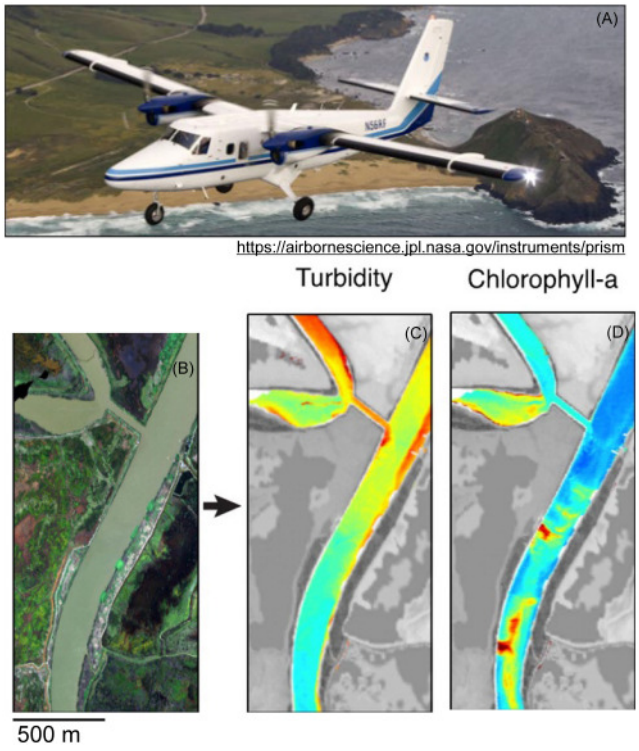

Figure 1

(A) Remote sensing imagery of turbidity and chlorophyll-a was measured using an airplane. **(B)** The imaged area is shown in a normal photo. **(C)** Turbidity is shown, with red as the most turbid and blue the least. **(D)** Chlorophyll-a concentrations are shown, with red as the most concentrated and blue the least (Image credit: [3]). Image has been modified after [3].

identify sources of pollution. Scientists can monitor water quality using sensors in the water. They also can monitor water quality remotely, from up in the sky. Scientists call this kind of monitoring **remote sensing** because it can be conducted without touching the water. Using satellites, airplanes, helicopters, and drones, scientists can have a bird's–eye view of an entire **estuary**. This way, they can collect data in much less time than they could in a boat or from shore.

Chlorophyll-a is a pigment found in plants and microscopic algae. Chlorophyll-a is an important indicator of water quality because it is a measure of algae growing in a waterbody. When algal concentrations are too high, they can lower the amount of oxygen dissolved in the water, and they can make animals and people sick. For example, chlorophyll-a makes microscopic algae—and the water they live in—appear green. The greenness of the water helps scientists see where and when these algae grow. Scientists use the term **algal bloom** to describe areas where microscopic algae are growing fast and covering large areas. Some algal blooms are poisonous. Scientists can measure how green the water is from the air, using remote sensing cameras designed to detect the various colors of sunlight reflected by the water [3]. Remote sensing makes it possible to map greener waters in the estuary where there are algal blooms. Maps of algal blooms show scientists where and when to monitor for microscopic algae directly from a boat or from shore. This information helps people and their pets avoid areas that could make them sick.

REMOTE SENSING

Gathering information about the environment at a distance, for example from an aircraft or satellite.

ESTUARY

Area at the end of a river where freshwater from the river mixes with saltwater from the ocean, creating water that we call brackish.

CHLOROPHYLL-A

A green pigment in plants and certain algae that captures the energy of the sun for photosynthesis.

ALGAL BLOOM

Rapid increase in the algae population in any body of water (river, lake, estuary, or ocean).

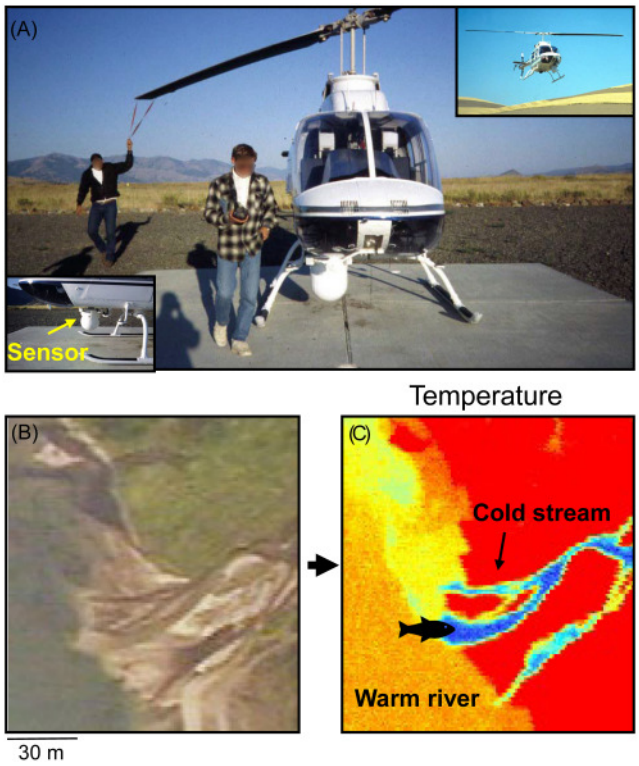

Figure 2

(A) Thermal infrared images were obtained with sensors mounted on a helicopter. **(B)** The imaged area is shown in a normal photo. **(C)** Temperature is shown from coldest (blue) to warmest (red). Note the cold stream entering the warm river. Coldwater fishes live primarily in the colder areas.

HOW DOES REMOTE SENSING WORK?

Remote sensors are like cameras that can "see" water quality by detecting energy coming from the water's surface. These sensors are mounted on satellites and a variety of aircraft (Figures 1, 2), each with their own pros and cons. Airplanes and helicopters can be flown at almost any time but monitoring trips are expensive and require a lot of planning. Drones take high-quality images and are inexpensive to fly, but their battery life is short. After 10–15 min, they must land to replace or recharge batteries. An advantage of remote sensing with satellites is that satellite images can cover large areas of the Earth, and the images are often free to download, but satellites only follow a specific orbit around the planet, which makes it impossible to choose the location and timing of monitoring.

Water quality indicators like chlorophyll-a reflect and emit energy from the water's surface. Remote sensing cameras detect this energy and use it to create an image like a photo. Like a camera, the human eye is a kind of remote sensor that sees sunlight reflected off the water in various hues of red, green, or blue. For example, chlorophyll-a in microscopic algal blooms reflects more green light than other colors. Muddy water has high **turbidity** and reflects more red and green light, making the water look brownish [3]. Heat is another kind of energy that comes from the water's surface, but we cannot see heat with our eyes.

TURBIDITY

A measure of how cloudy, or muddy, the water is, usually caused by floating particles that are too small to be seen without magnification.

THERMAL INFRARED CAMERA

A non-contact device that detects infrared energy (heat) and converts it into a visual image.

GROUND-TRUTHING

Process of comparing the data from an image obtained from remote sensing to data obtained on the ground or in the water.

Some snakes, like vipers, pythons, and boas, use special pit organs located between the eyes and nostrils to detect heat energy from a meter away [4]! The pit organ is used for finding prey. Remote sensing with a **thermal infrared camera** is like using rattlesnake vision to map water temperature, to see where water is too warm for fish and other aquatic organisms (Figure 2) [5].

Mapping and monitoring water quality from the sky is difficult. Scientists use a process called **ground-truthing** to make sure that measurements from the sky match measurements collected by scientists on the ground or in the water. Images from the sky may not be clear when it is too cloudy or smoky from wildfires. Also, because satellite images are taken from so far away in space, they are not very detailed. Aircraft and drones fly closer to the ground and may not cover large areas like satellites, but they provide very detailed images of small areas (Figures 1, 2).

HOW IS REMOTE SENSING USED IN THE SAN FRANCISCO BAY-DELTA?

Scientists in the San Francisco Bay-Delta estuary (California, USA) used remote sensing to measure turbidity and algal blooms in the water [3]. They investigated how these water-quality indicators interacted. The maps of turbidity and chlorophyll-a were very detailed and allowed researchers to identify sources of pollution. They also helped scientists and managers understand how wind, dry conditions, and floods can affect turbidity patterns that influence where fish live. Remote sensing of water temperature could also be used in the estuary to understand which areas are too warm for fish to live in [5].

WHY USE REMOTE SENSING IN THE SAN FRANCISCO BAY-DELTA ESTUARY?

The San Francisco Bay-Delta estuary is 200 km long and covers about 4,000 km^2. Sampling water quality by boat over such a large area is difficult, expensive, and time-consuming. It requires many people, boats, and lots of equipment. Because of this, most water-quality sampling occurs only once a month or even less. Using remote sensing, scientists can map and monitor many more locations in a short period of time. Remote sensing imagery can be combined with other data on weather and water flow to understand and conserve the estuary. Future technological advances will expand the capability of remote sensing and automated sensors to better complement data collected at monitoring stations and during boat surveys.

In summary, scientists learn a lot about the quality of the water in the San Francisco Bay-Delta estuary using remote sensing. This research is important because it helps scientists see where and when there might

be problems for human health or for the plants and animals living in the estuary.

ACKNOWLEDGMENTS

We thank Peggy Lehman from the California Department of Water Resources for inviting us to submit this manuscript. Patricia Haggerty from the U.S. Geological Survey, Forest, and Rangeland Ecosystem Science Center, Carl J. Legleiter from the U.S. Geological Survey, Geomorphology, and Sediment Transport Laboratory, and Nikolai Berntsen from Brandon Academy provided critical reviews that improved this manuscript. Editorial suggestions from Pedro Morais improved the readability of the manuscript for a broader audience. Imagery of the Pend Oreille River (Washington, USA) in Figure 2 was collected by Watershed Sciences, Inc. and provided by the Kalispel Tribe of Indians.

REFERENCES

1. Feyrer, F., Nobriga, M. L., and Sommer, T. R. 2007. Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. *Can. J. Fish Aquat. Sci*. 64:723–34. doi: 10.1139/f07-048
2. Brown, L. R., Komoroske, L. M., Wagner, R. W., Morgan-King, T., May, J. T., Connon, R. E., et al. 2016. Coupled downscaled climate models and ecophysiological metrics forecast habitat compression for an endangered estuarine fish. *PLoS ONE*. 11:e0146724. doi: 10.1371/journal.pone.0146724
3. Fichot, C. G., Downing, B. D., Bergamaschi, B. A., Windham-Myers, L., Marvin-DiPasquale, M., Thompson, D. R., et al. 2016. High-resolution remote sensing of water quality in the San Francisco Bay-Delta estuary. *Environ. Sci. Technol*. 50:573–83. doi: 10.1021/acs.est.5b03518
4. Fang, J. 2010. Snake infrared detection unravelled. *Nature*. doi: 10.1038/news.2010.122. Available online at: `https://www.nature.com/articles/news.2010.122`
5. Dugdale, S. J. 2016. A practitioner's guide to thermal infrared remote sensing of rivers and streams: recent advances, precautions and considerations. *Wiley Interdiscip. Rev. Water*. 3:251–68. doi: 10.1002/wat2.1135

SUBMITTED: 20 October 2020; **ACCEPTED:** 14 February 2022;
PUBLISHED ONLINE: 14 March 2022.

EDITOR: Pedro Morais, Florida International University, United States

SCIENCE MENTOR: Yoed Nissan Kenett

CITATION: Mejia FH, Torgersen CE and Fichot CG (2022) Keeping an Eye on Water Quality From the Sky. Front. Young Minds 10:619716. doi: 10.3389/frym.2022.619716

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YOUNG REVIEWER

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A huge Harry Potter fan! I love reading books! I spend many hours reading on my Kindle, especially Harry Potter—I have read the entire series 20 times! I also love jamming on my electric piano, jump-roping, and skipping when I am happy. I like eating salads and home cooked meals, but I also have a big sweet tooth—chocolate is yummy! As a vegetarian, I love nature—learning about it, protecting it, and enjoying it!

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Cédric Fichot is an assistant professor in the Department of Earth and Environment at Boston University, in Boston, MA, USA. He has always loved outer space and the underwater world. As a kid, he spent many of his summers snorkeling in Corsica and exploring what is below the water surface. Cédric now uses remote sensing to study aquatic environments. He loves to go hiking and to spend time outside with his wife and their three children.