Remote Sensing Verification of Conservation Tillage BMPs

CBP Agriculture Working Group

Thomas Howard

February 15, 2024

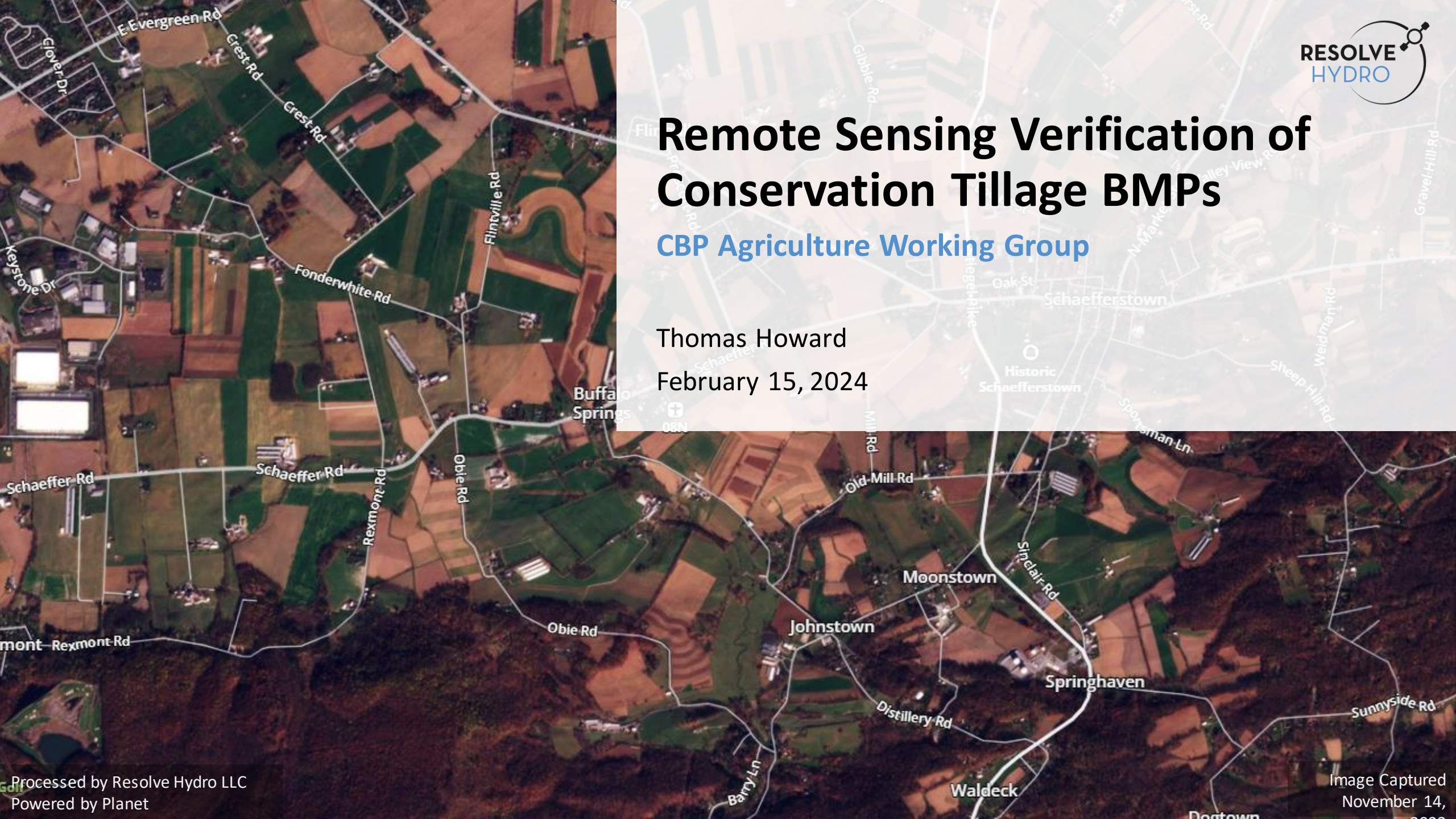

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Image Captured November 14,

Remote Sensing Verification of Conservation Tillage BMPs

Thomas Howard

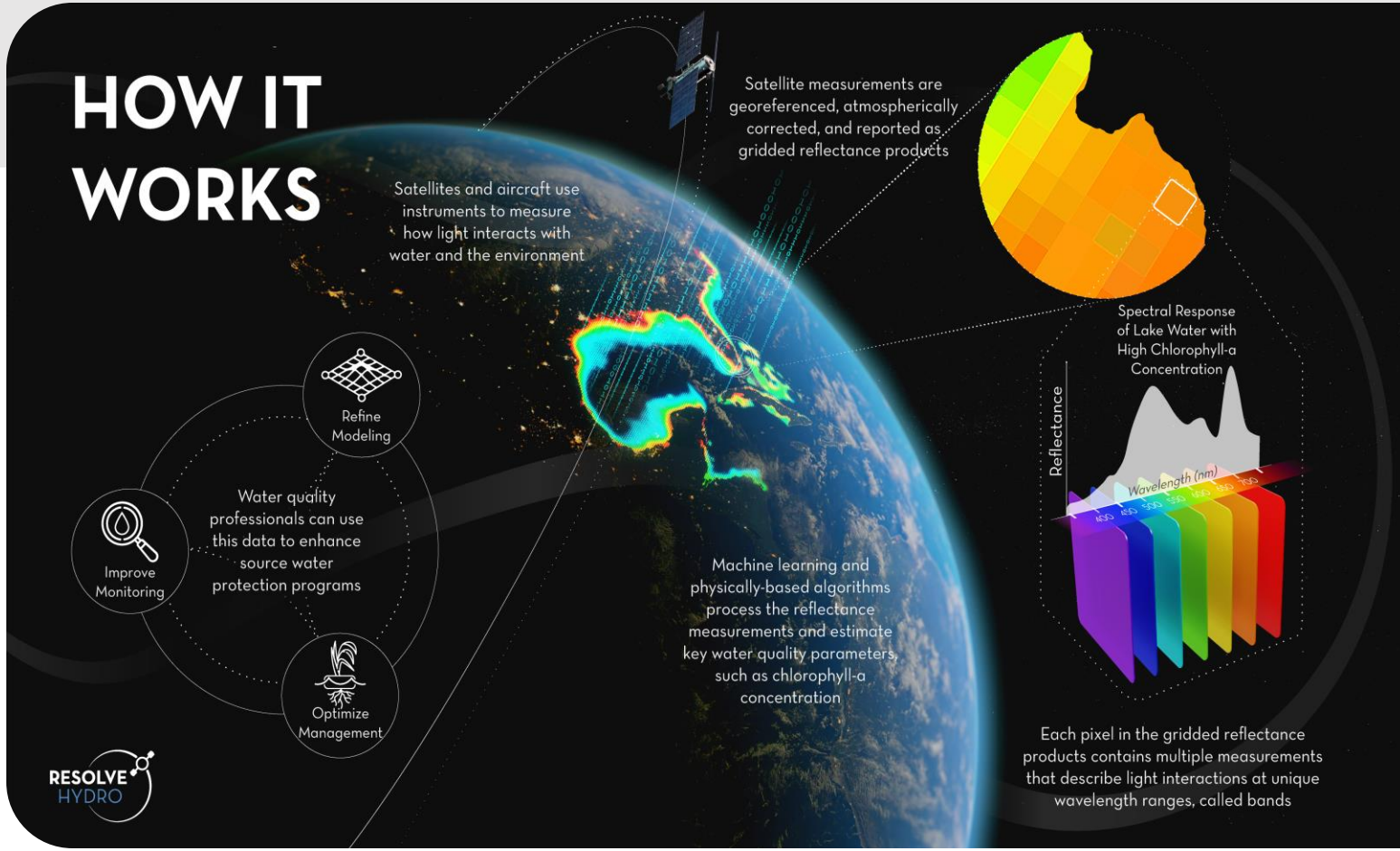
Founder & CEO
Resolve Hydro LLC

Agenda for Today's Presentation:

- Introduction, Motivation, and Background
- Example Applications of Remote Sensing
- PA DEP Methodology Development Plan for Remote Sensing Verification of Conservation Tillage BMPs
- Next Steps, Future Opportunities, and Discussion

Satellites measure light energy reflected into space after it has interacted with the Earth's surface and atmosphere

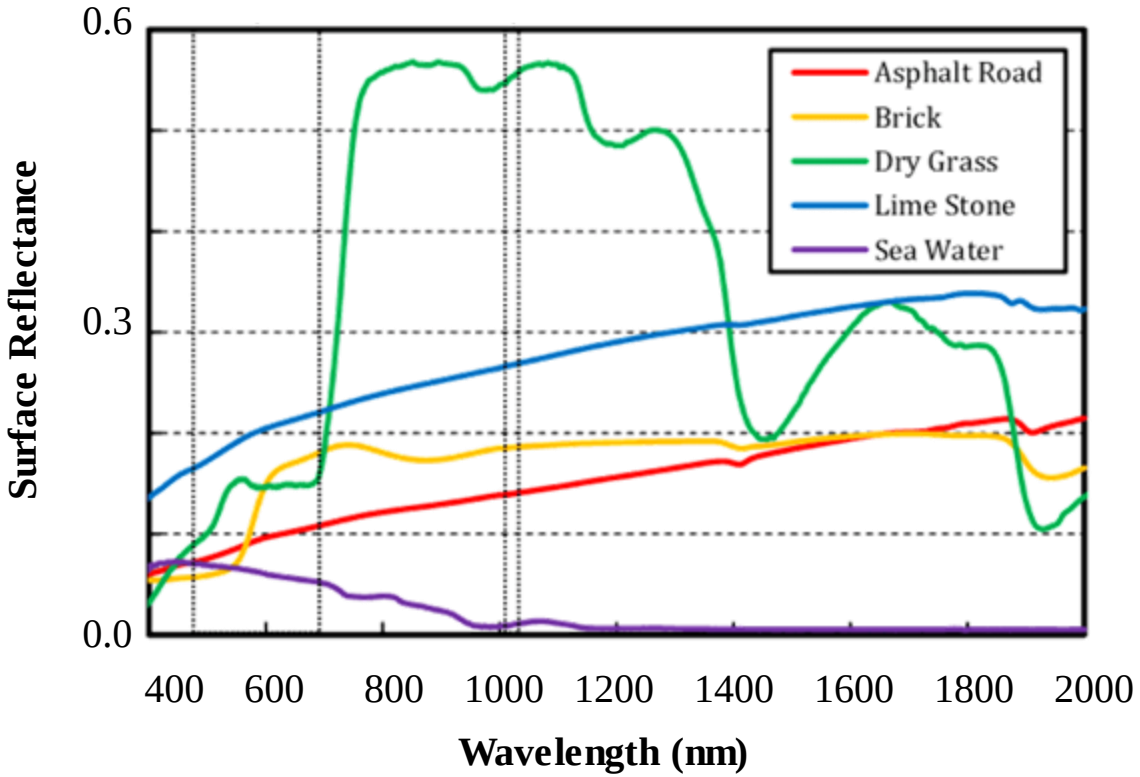
How can satellites 300-miles away be used to monitor our environment?

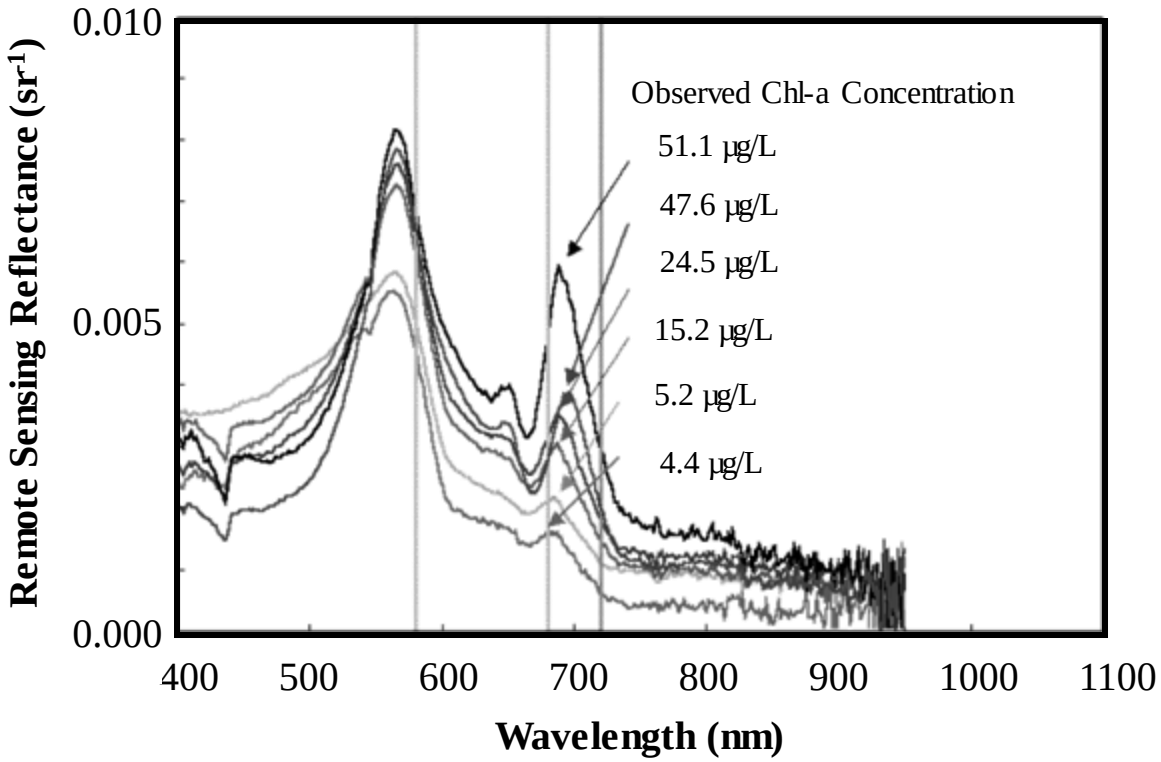


1. Radiation is emitted from the sun (or another active source)
2. Ozone, aerosols, and other atmospheric constituents absorb and scatter light energy
3. Light reaching the surface interacts with matter in wavelength-dependent, physically predictable ways
4. Light scattered back through the atmosphere is measured by satellites
5. Usable data products are created

Remote sensing can identify different materials and provide quantitative and qualitative information about the material's conditions and processes

Reflectance Provides a Spectral Fingerprint for Different Materials





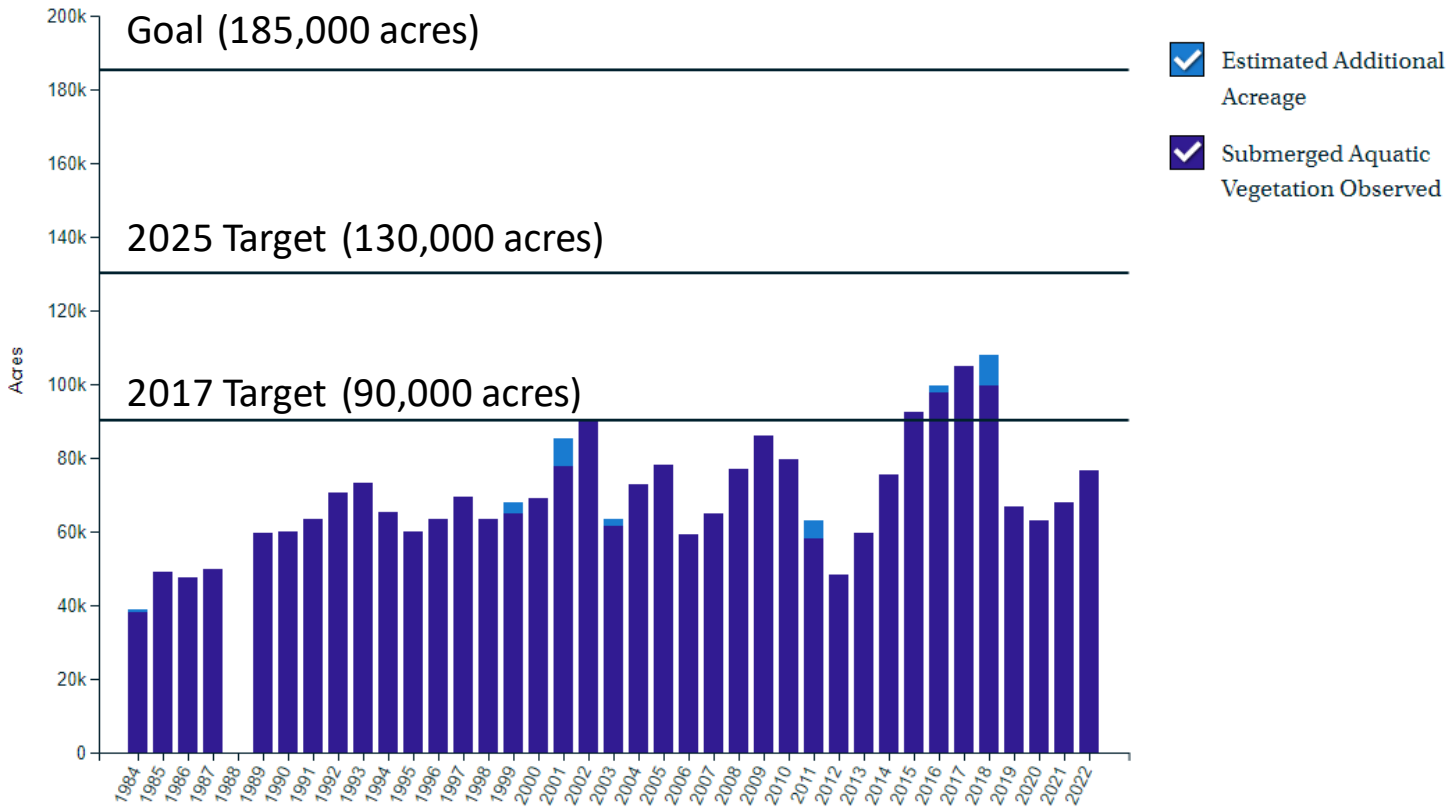
Yan, Shaker, and El-Ashmawy (2015)

Yan et al. (2006)

Remote Sensing Application Example 1: Aquatic Vegetation Monitoring

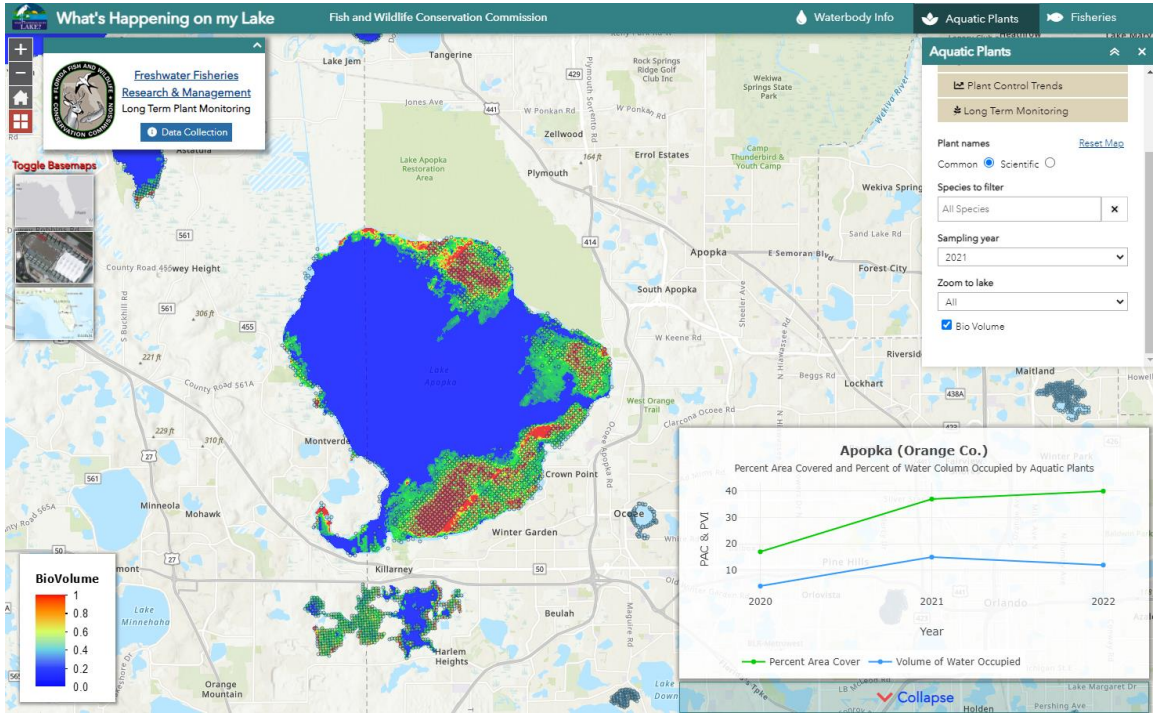
The Chesapeake Bay Program has set a goal to achieve and sustain 185,000 acres of SAV Bay-wide

- Since 1984, the Chesapeake Bay Program has worked with Virginia Institute of Marine Science (VIMS) to conduct an **annual survey of SAV** throughout the Chesapeake Bay
- In 2017, the cost for aerial imagery alone was **$140,000** (total survey budget of $689,000)
- Beginning in 2021, the price for aerial imagery was expected to increase 1.7-2.1 times (**$238,000 - $294,000**)
- The cost to collect PlanetScope imagery for the entire Bay is under **$20,000**



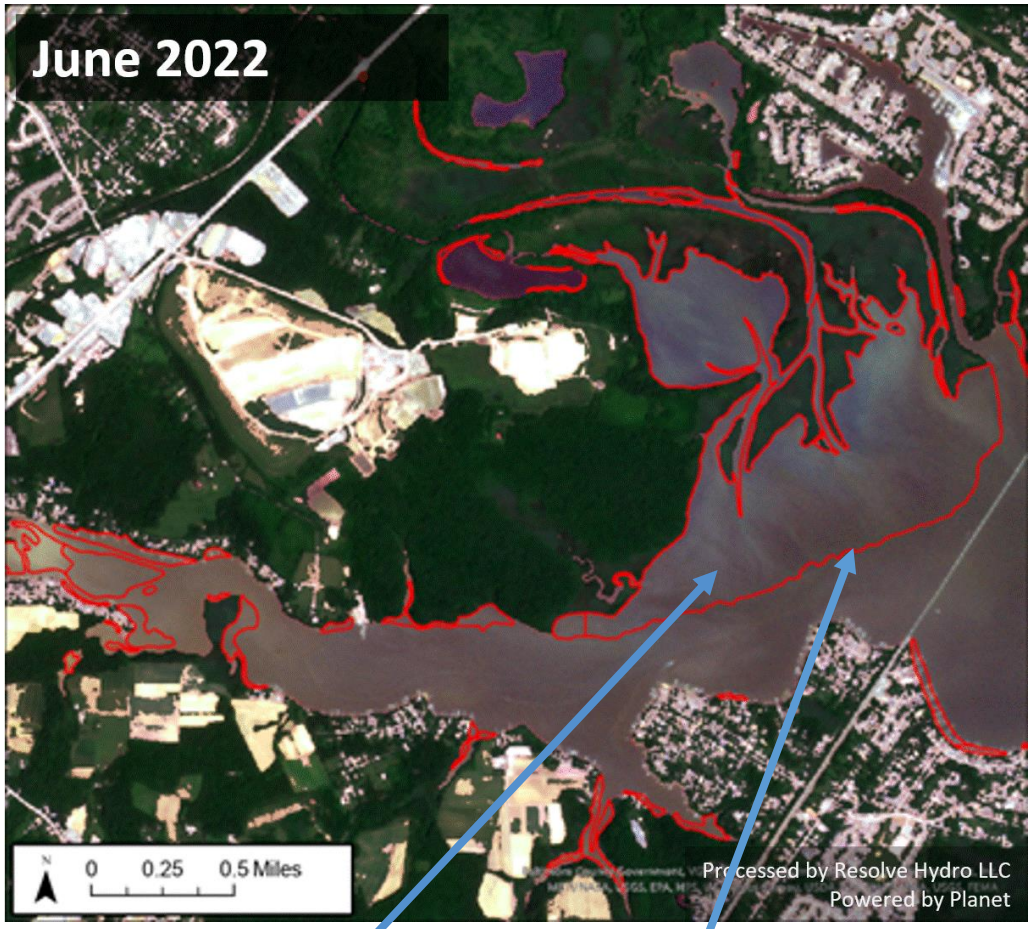
Remote Sensing Application Example 1: Aquatic Vegetation Monitoring

Satellite imagery can quickly map SAV coverage with minimal processing



16,735 sample points from 37 different waterbodies throughout Florida were used to train a machine learning model to predict presence/absence of aquatic vegetation

Testing on 7,156 sample points from these lakes showed the trained classifier had **86% accuracy**

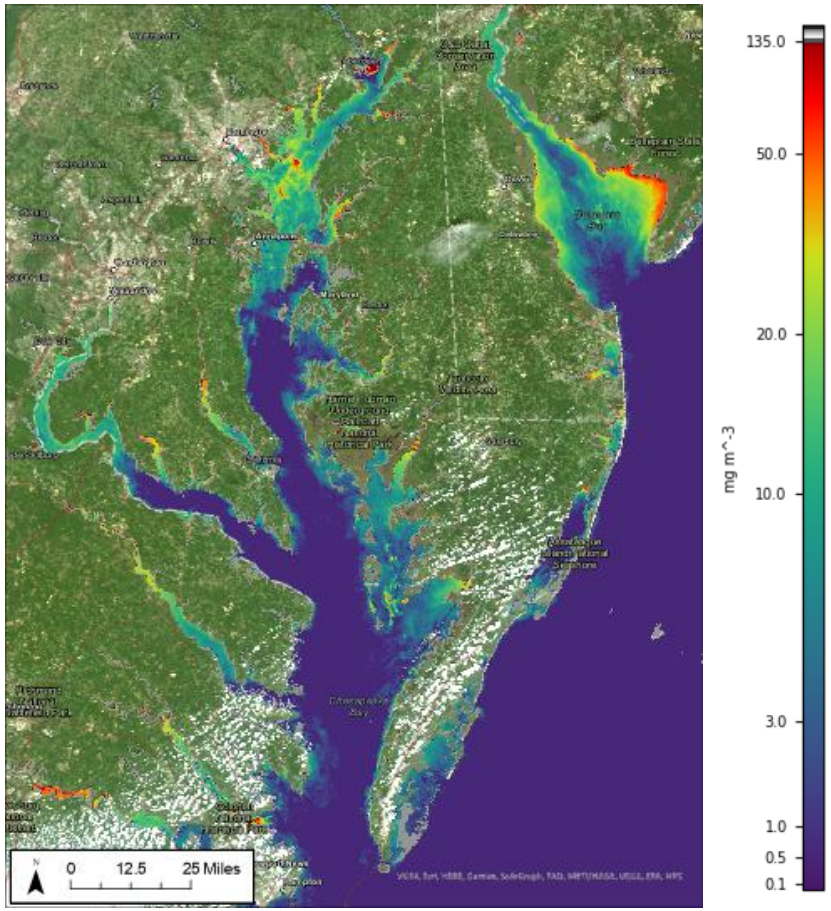


Satellite-derived SAV extent

2022 SAV Bed Outline (VIMS)

Remote Sensing Application Example 2: Water Quality Monitoring

Machine learning and physically-based algorithms can accurately estimate surface water quality parameters like chlorophyll-a



Sentinel-3B/OLCI Image Captured 08/20/2023 at 3:11 pm

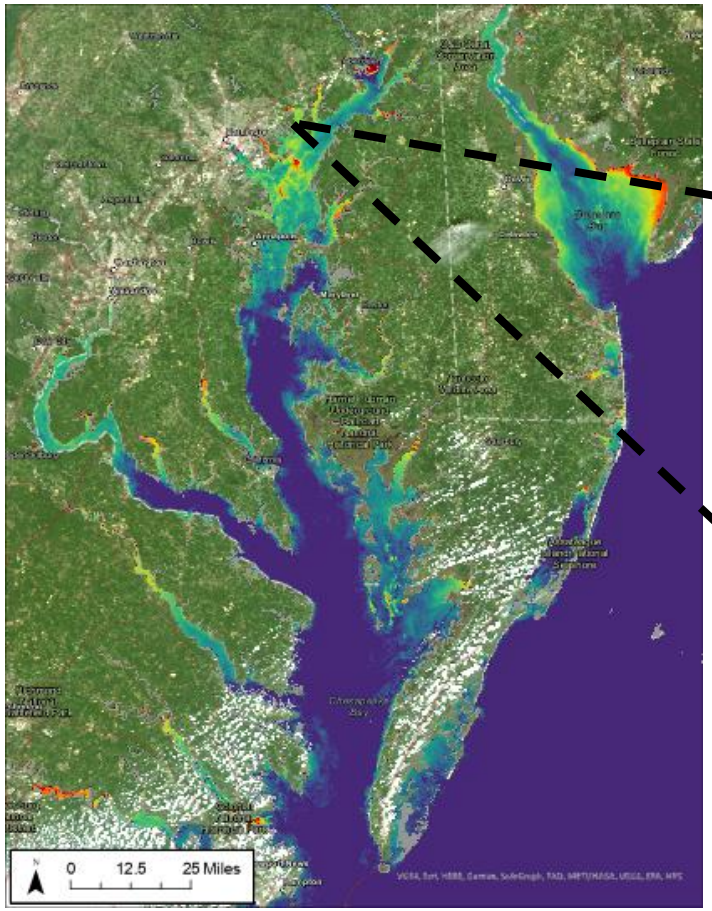
Q: Why hasn't this "game-changer" integrated into inland water quality monitoring programs in the last 50 years?

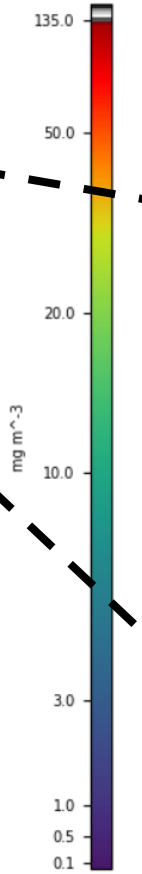
NOAA's NCCOS Algal Bloom Beta/Experimental Products map shows estimated chlorophyll-a concentration in mg/m^3 throughout the Chesapeake and Delaware Bays.

Remote sensing, used in conjunction with traditional monitoring tools, offers a **low-cost way to synoptically describe land and water conditions through space and time**

Remote Sensing Application Example 2: Water Quality Monitoring

Machine learning and physically-based algorithms can accurately estimate surface water quality parameters like chlorophyll-a





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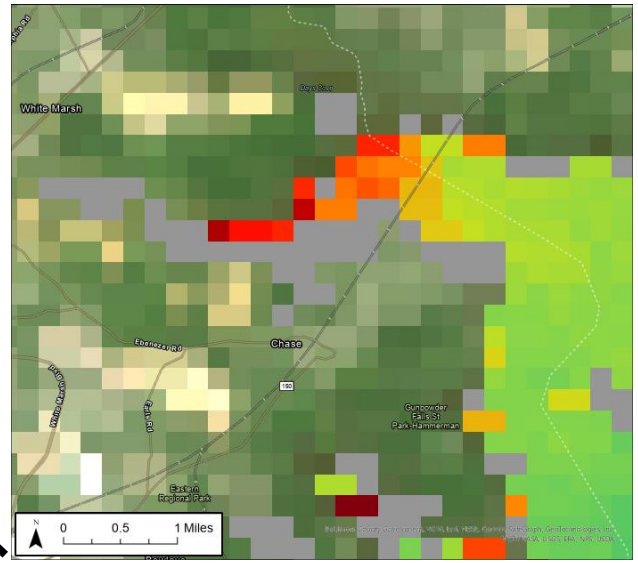
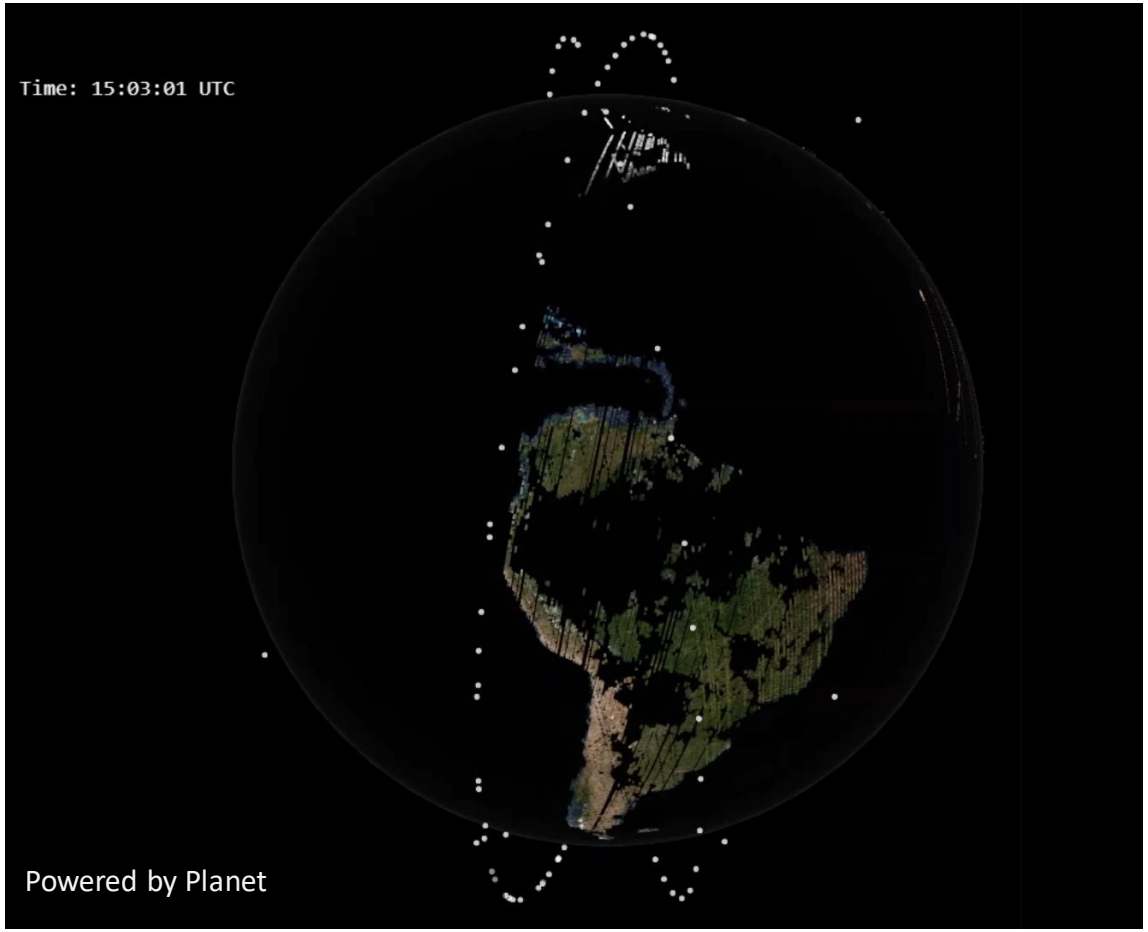


A: It's been hindered by a lack of suitable sensing systems, detection algorithms, and industry training.

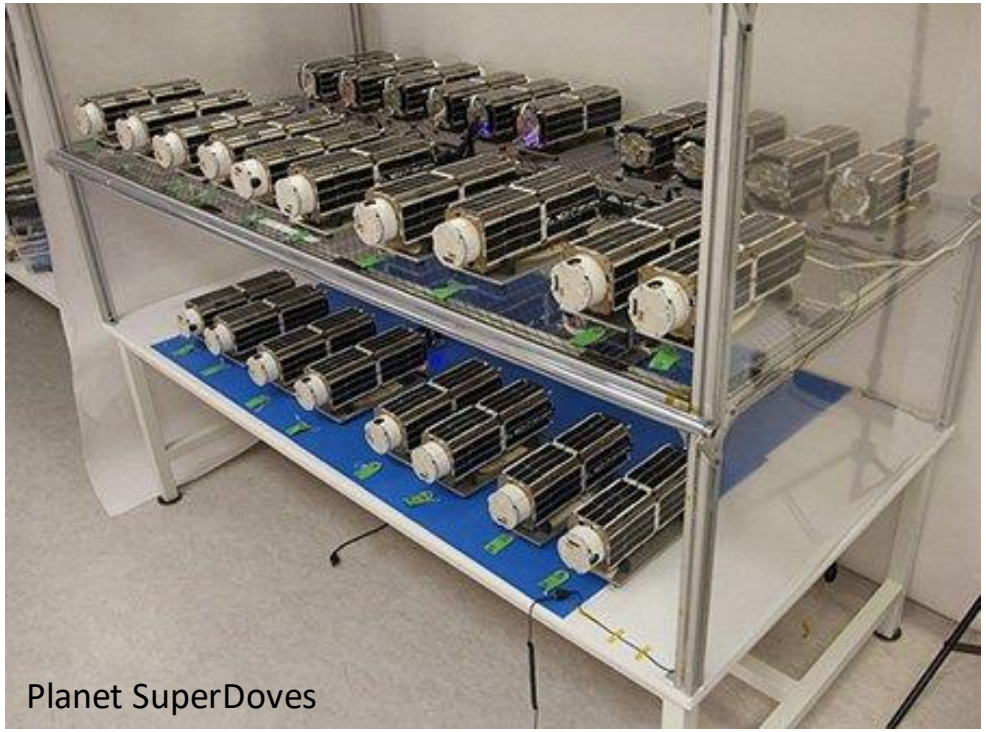
Remote sensing, used in conjunction with traditional monitoring tools, offers a **low-cost way to synoptically describe land and water conditions through space and time**

Resolve Hydro uses constellations of CubeSats to overcome traditional limitations with remote sensing

High spatial, temporal, and spectral resolution provides enhanced data for water resources applications



Planet SuperDoves collect daily, 8-band imagery over the Earth's entire land area. Data are available from March 2020 to the present.


Planet SuperDoves

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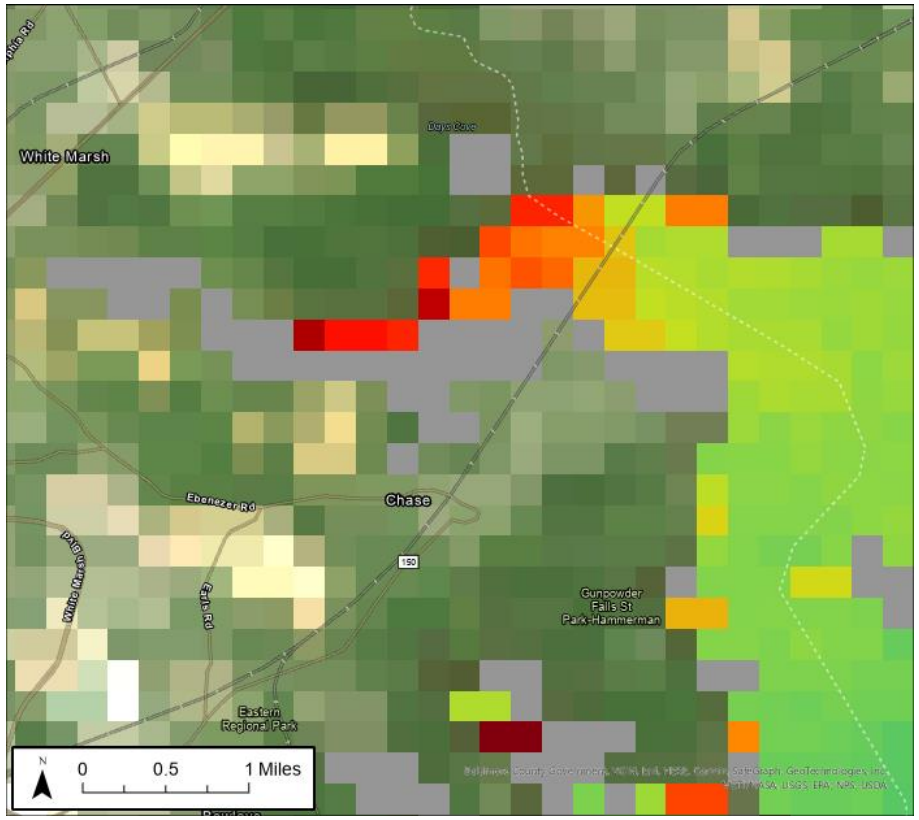

Sentinel-3B/OLCI Image Captured 08/20/2023 at 3:11 pm

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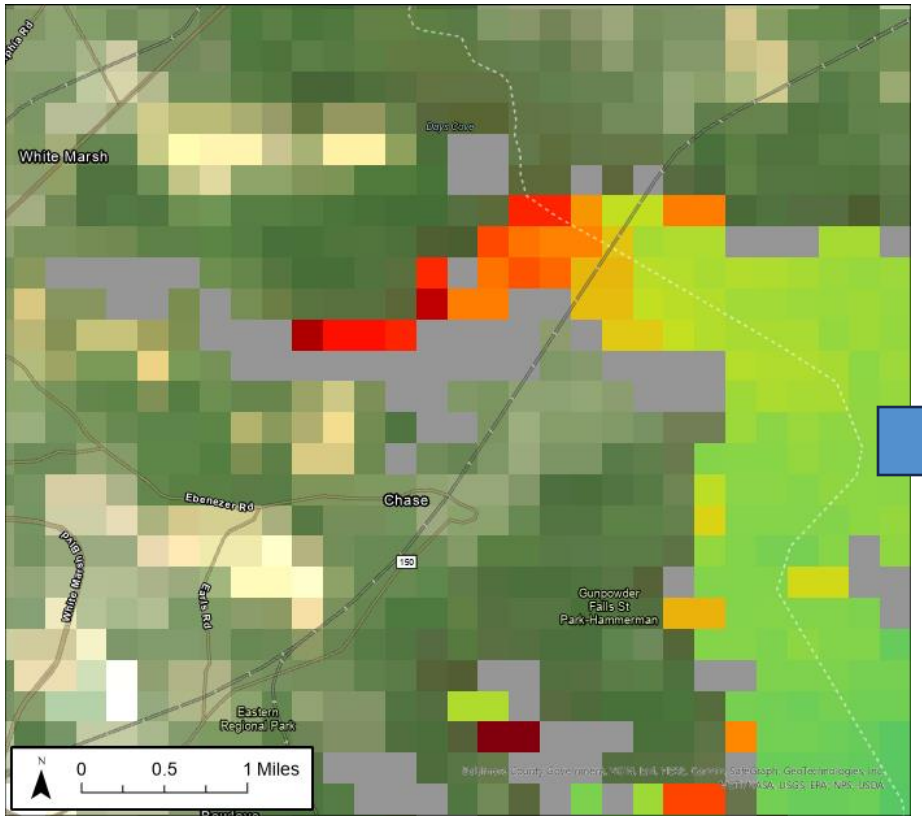
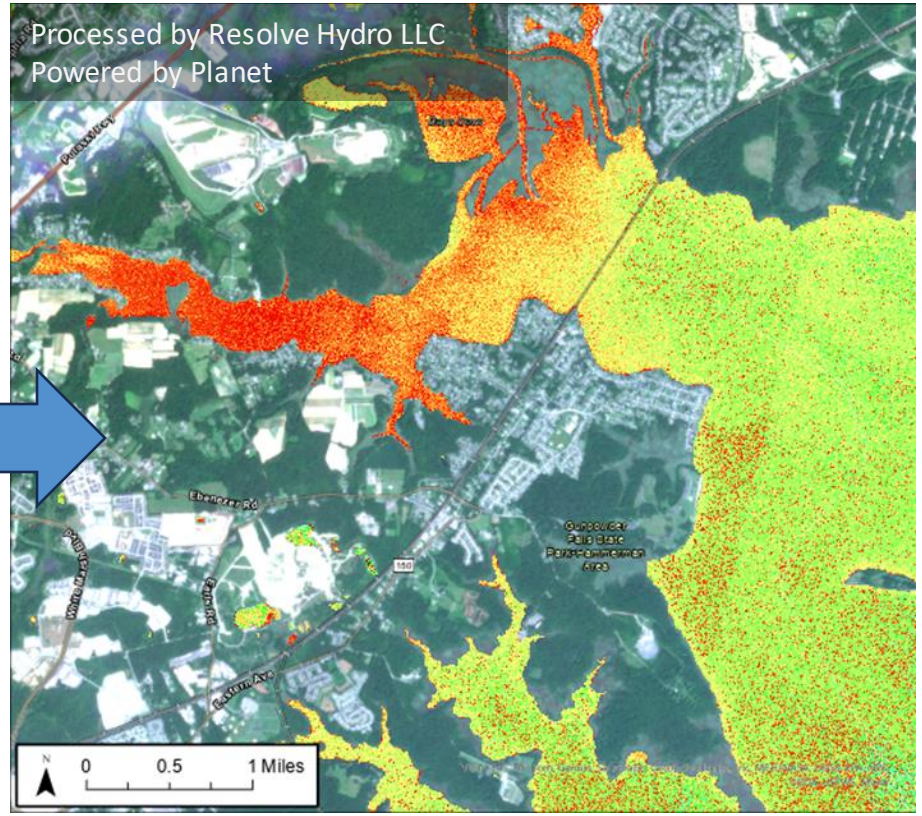


Sentinel-3B/OLCI Image Captured 08/20/2023 at 3:11 pm



Planet SuperDove Image Captured 08/20/2023 at 3:37 pm

The enhanced resolution of SuperDove satellites allow us to monitor over 200,000 new waterbodies in the US

Remote Sensing Example 3:

PA DEP Methodology Development Plan for Remote Sensing Verification of Conservation Tillage BMPs

Remote Sensing Application Example 3: Conservation Tillage

Conservation tillage minimizes soil disturbance and leaves a higher amount of crop residue in fields

Conventional Tillage: Any tillage routine that does not achieve 15% crop residue coverage immediately after planting

Low Residue Tillage: A routine that maintains 15% to 29% crop residue coverage immediately after planting each crop.

Conservation Tillage: A routine that maintains 30% to 59% percent crop residue coverage immediately after planting each crop.

High Residue, Minimum Soil Disturbance Tillage: A routine that maintains at least 60% crop residue coverage immediately after planting each crop.

Conservation tillage minimizes disturbance to the soil and reduces nitrogen, phosphorus, and sediment loads to receiving waters

Conservation tillage offers field-level advantages as well as broader ecological benefits

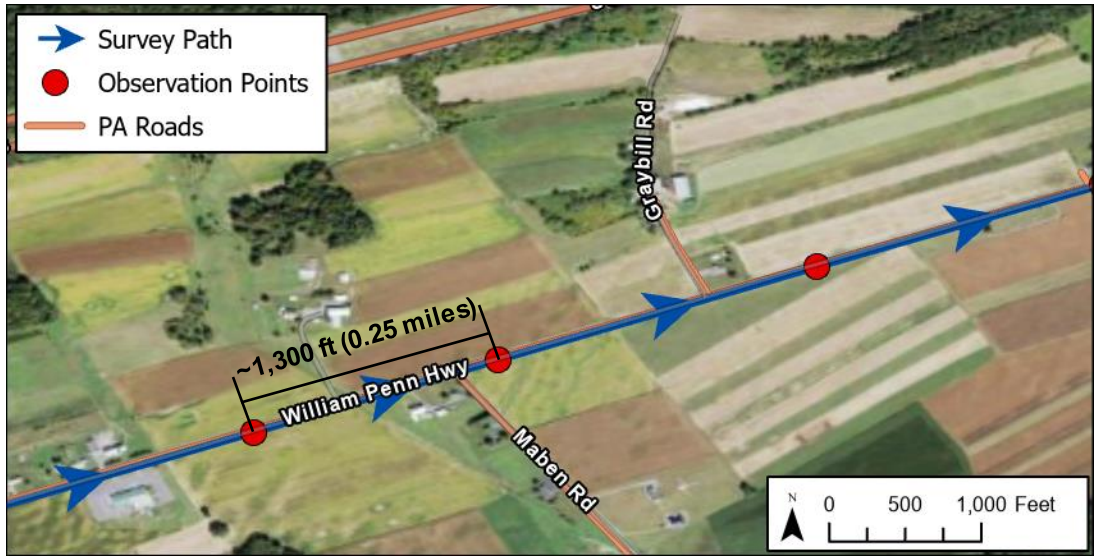
- Reduced Soil Erosion
- Increased Carbon Sequestration
- Increased Water Infiltration
- Reduced Labor, Time, and Costs

	Nitrogen Reductions (%)	Phosphorus Reductions (%)	Sediment Reductions (%)
Low Residue	2 – 5	6 – 9	18
Conservation Tillage	4 – 10	2 – 60	41
High Residue	12 – 15	11 – 74	79

Nitrogen, Phosphorus, and Sediment Efficiency Value Reductions for Tillage Practices Implemented in the Chesapeake Bay Vary by Hydrogeomorphic Regions

Roadside transect surveys are the primary method used for reporting conservation tillage practices in Pennsylvania

- In PA, 33 counties are surveyed over a two-period (total cost of **~$300,000**)
- Each county survey team is staffed with at least three individuals



The 2023 Spring Tillage Survey included 800+ observations throughout Juniata County

Anticipated Mileage for 2024 Spring Tillage Survey	
County	**Miles Driven**
Bradford	286
Centre	236
Clinton	169
Columbia	221
Lancaster	437
Lebanon	215
Luzerne	256
Lycoming	221
Mifflin	322
Montour	251
Northumberland	232
Schuylkill	293
Sullivan	212
Susquehanna	180
Tioga	343
TOTAL	**3,874**

Research has shown remote sensing can accurately detect crop residue

Soil, residue, and vegetation exhibit distinct spectral properties discernable by various satellite platforms

Using Sentinel-1, Sentinel-2, and Planet satellite data to map field-level tillage practices in smallholder systems

Yin Liu, Preeti Rao, Weiqi Zhou, Balwinder Singh, Amit K. Srivastava, Shishpal P. Poonia, Derek Van Berkel, Meha Jain

Published: November 28, 2022 • https://doi.org/10.1371/journal.pone.0277425

"We found that when considering a single sensor, the model that used Planet imagery (3 m) had the highest classification accuracy (86.55%) while the model that used Sentinel-1 data (10 m) had the lowest classification accuracy (62.28%)."

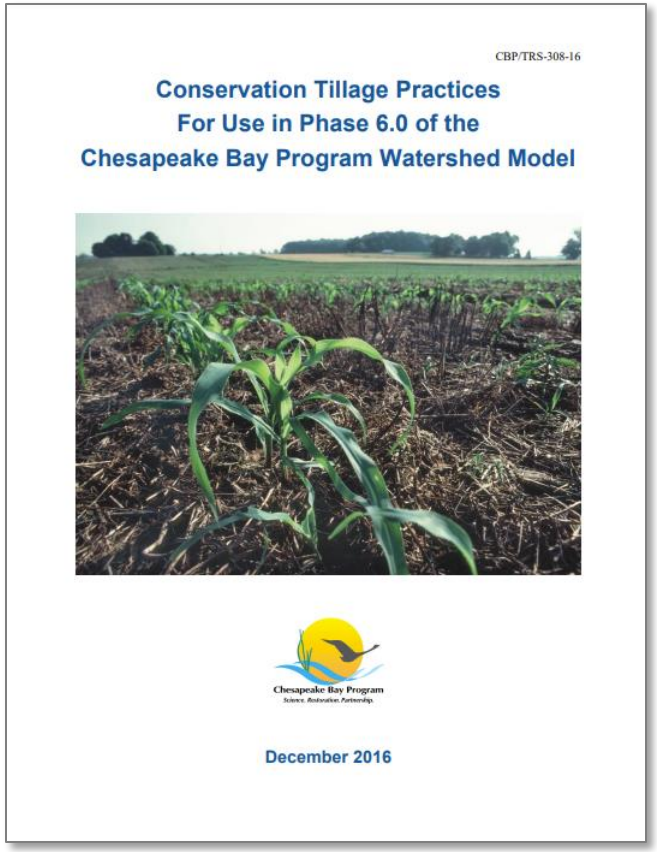
Utility of daily 3 m Planet Fusion Surface Reflectance data for tillage practice mapping with deep learning

Dong Luo [a], Hankui K. Zhang [a,*], Rasmus Houborg [b], Lina M.N. Ndekelu [a], Maitiniyazi Maimaitijiang [a], Khuong H. Tran [a], John McMaine [c]

April 26, 2023

"Classification accuracy continuously increased with increases in both temporal and spatial resolutions. The optimal models (3D CNN and attention CNN-LSTM) achieved ~77% accuracy using 2-day or daily 3 m resolution data…"

Prior CBP reports have identified the potential for remote sensing to supplement BMP verification of conservation tillage practices


CBP/TRS-308-16

Conservation Tillage Practices
For Use in Phase 6.0 of the
Chesapeake Bay Program Watershed Model

Chesapeake Bay Program

December 2016

4.4 Modeling Considerations

Verification will be possible through field visits (using CTIC protocol) and records of implementation of NRCS practice codes, either 329 or 345. Remotely sensed (aerial/satellite) estimates are also likely feasible given proper calibration.

5.2 Future Verification of Conservation Tillage Practices

The Panel envisions that potential opportunities may exist in the future for utilizing alternative forms of BMP verification, such as remote sensing from satellite, aerial, and drone imagery.

6 Data Gaps and Research Needs

Calibration of remotely-sensed information for residue cover data should be continued and expanded through the watershed.

Pilot Project Research Questions

Throughout a **PA-based pilot project**, we aim to answer questions related to both the practicality and science of using remote sensing for BMP verification of conservation tillage practices

- Compared to traditional methods, how **accurate and sensitive** are remote sensing approaches for conservation tillage BMP verification?
- What **cost, labor, time, and resource savings** would a remote sensing BMP verification method provide?
- What **new information** can remote sensing data provide? What **information is lost**?
- How much **ancillary data and field data** is needed to train, test, and implement a remote sensing BMP verification methodology?
- What demonstrations and **analyses are needed to validate** a new remote sensing-based verification methodology?
- How can this data **inform future monitoring and management** decision?

Proposed Pilot Project

Remote Sensing-Based Verification of Conservation Tillage BMPs

Phase 1: Methodology Development Plan

(Spring 2024)

- Develop a comprehensive plan and **written report** documenting how to develop and evaluate a method for remote sensing-based verification of conservation tillage practices

Phase 2: Method Development and Evaluation

(Summer 2024 – Winter 2025)

- Train and test **machine learning models** that use satellite imagery to classify the degree of conservation tillage in a field (e.g., >60% residue)
- Develop and evaluate a **BMP verification methodology** and report

Phase 3: Implementation

(Spring 2025)

- Employ the model and method generated in Phase 2 to **characterize conservation tillage implementation** in agricultural areas located in the PA jurisdiction of the Chesapeake Bay Watershed during the 2025 season

Proposed Pilot Project Timeline

PA-DEP Remote Sensing-Based Verification of Conservation Tillage BMPs Pilot Project

Phase 1: Methodology Development Plan

March 2024 to June 2024

Presentation to AgWG on Methodology Development Plan

Phase 2: Method Development and Evaluation

June 2024 to January 2025

Independent Review

Vote for AgWG Approval of Developed Methodology

Phase 3: Implementation

March 2025 to July 2025

Chesapeake Bay Program
Science. Restoration. Partnership.

We seek to obtain AgWG feedback and official approval on the developed methodology at the end of Phase 2 of the pilot project.

Agriculture Workgroup Engagement

Throughout the project, the Agriculture Workgroup can provide critical feedback informing project outcomes and method development

AgWG Engagement Opportunities

- Data sharing and Progress Reporting
- Technical Advising Committee Participation
- Independent Review
- Method Evaluation and Approval

Discussion Questions

1. Do you agree that the use of high-resolution satellite data has the potential to supplement cropland roadside transect surveys and enhance BMP verification of conservation tillage practices?

2. Do you agree the Agriculture Workgroup is the appropriate workgroup to provide approval of this methodology after completion of a PA-based pilot project and review by partners?

RESOLVE HYDRO

THANK YOU

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