NEW YORK
STATE OF
OPPORTUNITY

Department of
Environmental
Conservation

Using CSLAP data & Satellite Images to estimate Chlorophyll-a

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NYSFOLA Conference

3rd May 2019

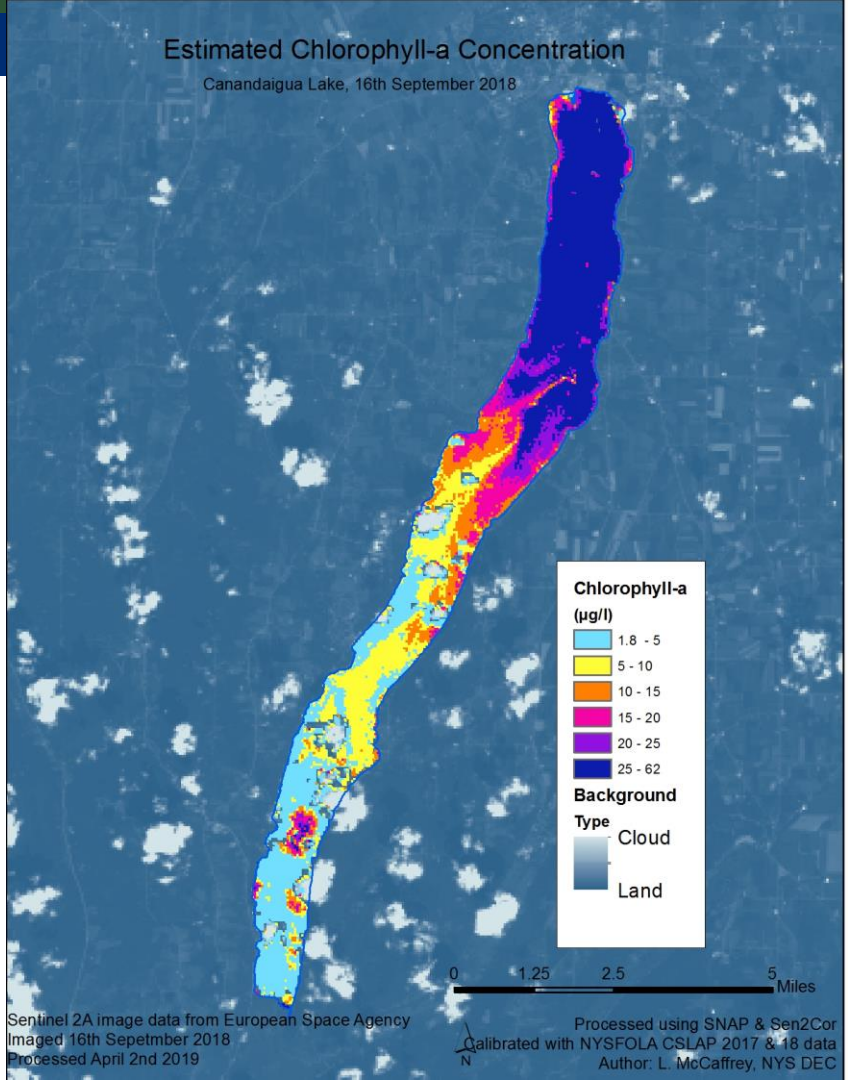
For example

Starting with raw satellite images….

Processing them to get useful information such as…

36 % of visible lake surface has Chl-a >25 µg/l

Thanks to CSLAP volunteers!



Contents

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2. Satellite options
3. Pilot projects
4. Next steps

Builds on work by NASA, NOAA, Baird and others

Source: NOAA

Program needs

What now defines a bloom? Concentration

Monitoring data

- Bloom metrics derived from interpretation of WHO criteria
  - “Moderate probability of adverse health effects” = 50 ug/l chlorophyll a (Chl-a) with a dominance of BGA
  - Interpreted by DEC as 25 ug/l BG Chl-a (measured by a bbe fluoroprobe)
- Fluoroprobe metrics (> 25 ug/l BG Chl-a) measured in samples collected by CSLAP, DEC, or other trained partner samplers
- Samples collected from “worst” (most intensive visual) part of bloom as surface skim samples, or routinely from open water samples (1.5m grab samples in CSLAP or 0-2m integrated sample from LCI)

https://www.who.int/water_sanitation_health/bathing/srwe1-chap8.pdf

What now defines a bloom? Looks

Visual assessments

- Visual or digital evidence of blooms from public surveyors (verified by DEC)
- Beach closures based on DOH beach managers assessment of likely blooms

This is based on assessment (assumption?) that symptoms are not likely unless the accumulation of cyanobacteria is dense enough to be visible

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https://www.who.int/water_sanitation_health/bathing/srwe1-chap8.pdf

What now defines a bloom? Size

Spatial extent definitions derived from Conesus Lake surveillance definitions (< 2012)

Samplers instructed to evaluate spatial extent as (one of):

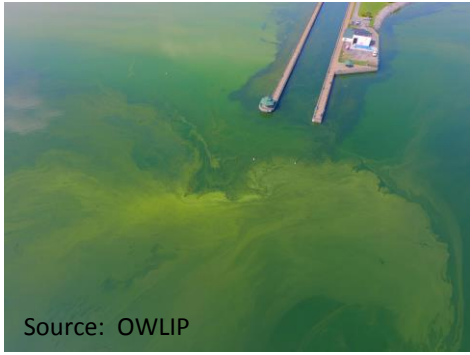
- Small localized
- Large localized
- Widespread/Lakewide
- Open water

CSLAP and LCI samplers asked to survey most to all of lake

Partner surveillance program “zones” up to 1 mile wide, but effective survey area more likely = 50-100 meters

Skaneateles Lake 16 Sept 2017

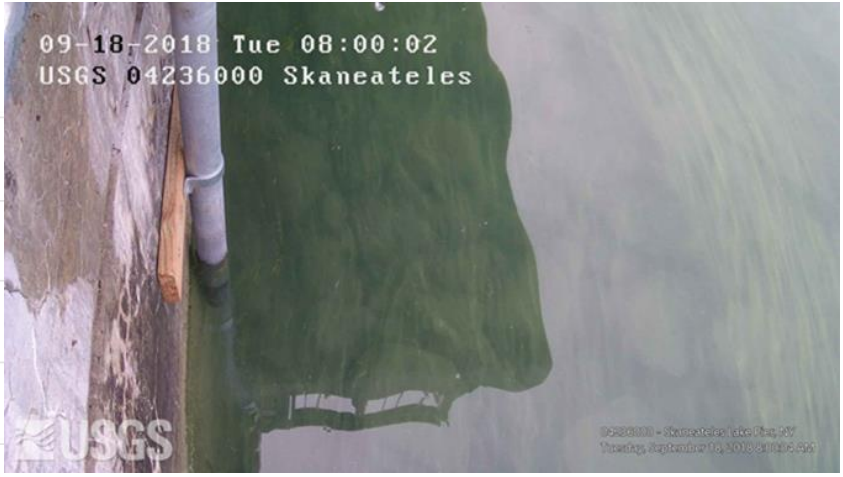
Owasco Lake 19 Sept 2017

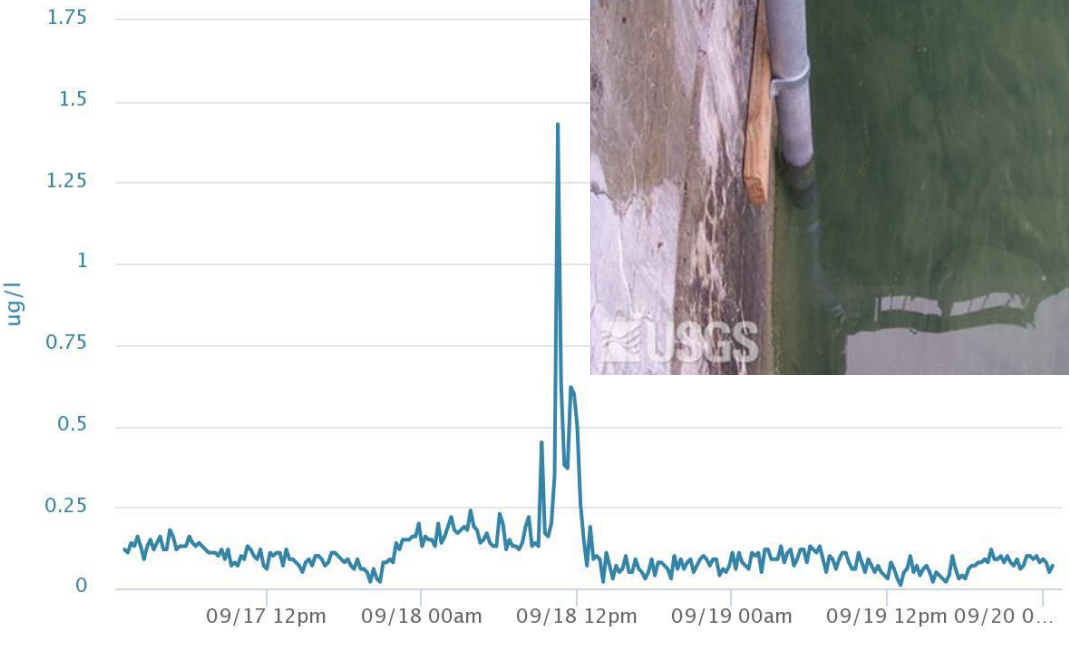


What now defines a bloom? Persistence

- CSLAP samples generally collected in **two week** intervals
- LCI samples generally collected in **one month** intervals, and public reports likely **one-off/single report** events, with no follow up
- Some (few) instances of local bloom reports in between **2-4 week** intervals
- Partner surveillance programs collected in **one week** intervals
- Multiple occurrences over summer could be extrapolated for “much” of the recreational season
- →

What now defines a bloom? Persistence





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Using bloom information: Lake Assessments

NYS DEC must assess lake status; done using CALM:

Impaired = "NYS/County Health Department or local health agency has issued temporary/occasional closures of public bathing beach(es) in the waterbody for between 10 and 25 days." (based on HABs); ***or*** "Presence of HABs", with "presence of HABs"defined as:

> "*occurrence on **multiple days** and **verified** over more than a 2 week period, at **multiple locations** covering **significant spatial extent**, with **likelihood of annual recurrence***"

Stressed = "**Occasional occurrence** of harmful algal blooms (HABs) of less than 2 week duration", but NO required citation through *NYSDEC Harmful Algal Bloom notification criteria*

Threatened = no HABS criteria (Fully Supported = "no **significant** occurrence of HABs have been reported")

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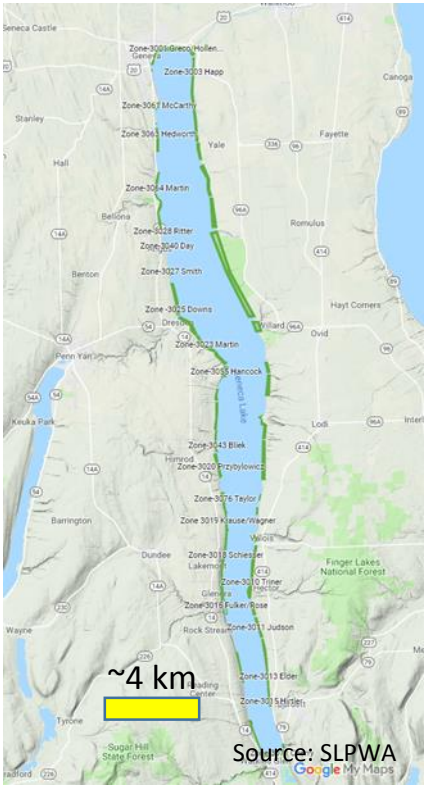
Current NYS HABs Metrics: Limitations

CALM definition of “significant spatial extent” operationally defined as “widespread” or “large localized” in many (most?) locations

Bloom extent on larger waterbodies cannot be evaluated through existing surveillance networks on large lakes

- “Large localized” definition is a mix of absolute measurements (“many properties”) and relative measurements (“large segment of the shoreline”)
- Surveillance zone can only evaluate a small portion of the lake, so relative measure of “large localized” cannot be achieved
- Summation of surveillance zones, even in Seneca Lake (>75 zones), does not constitute majority of shoreline or open water conditions
- “Widespread” cannot be credibly evaluated in large waterbodies



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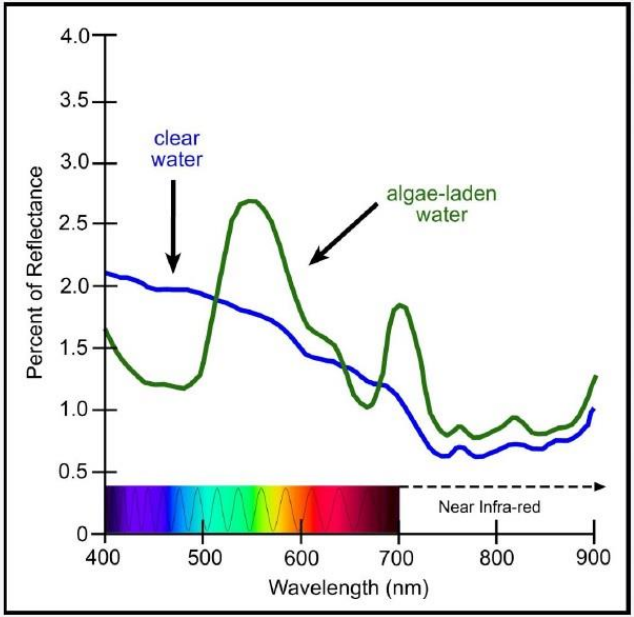
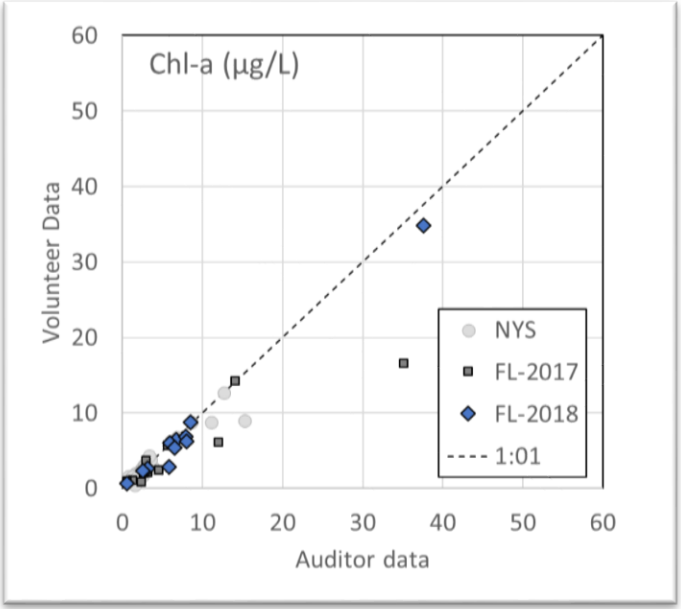
Satellite options

How green is your lake?



Percent reflectance of clear (blue) and algae-laden (green) water (data from Han, 1997).



Value of satellite data for assessments

Satellite spectral data can be correlated to measured (surface) Chl-a

Spatial extent of surface conditions can be estimated for waterbodies from as little as 4 acres in size (based on satellite resolution)

Temporal frequency, can be as frequent as 5 days, may be sufficient for overall waterbody recreational assessments

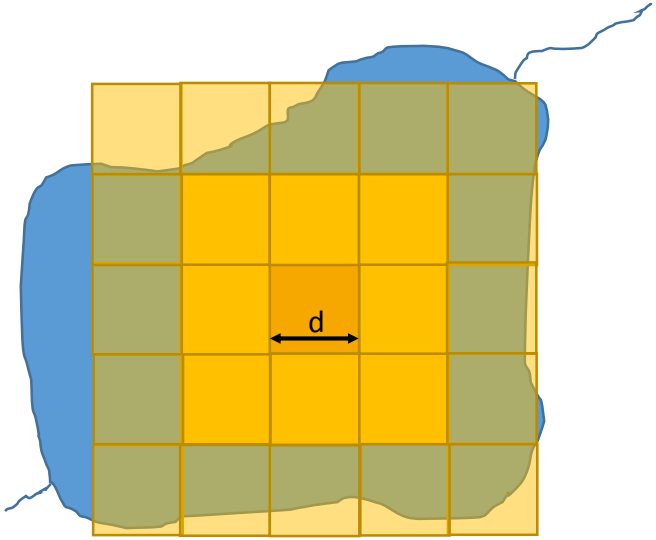
Satellite data NOT appropriate for

- public notification program (delayed and less likely to evaluate shoreline blooms)
- evaluation of potable water (cannot assess conditions at water intake depth)
- evaluation of public bathing (poor spatial resolution for small beach areas near shore)

Source: OWLIP

Pixel limitations – minimum size

- Pixel size limits the minimum dimensions of a lake which can be imaged
- Best to average the pixels surrounding the sample site
- 3 x 3 minimum recommended
- Expanding the averaged pixel numbers eventually runs into the ‘mixed pixel problem’



Pixel length = d

Minimum lake dimension = 5d

Pixel limitations – minimum size

Source: ESA

E.g. Buckingham Pond near Albany

Smallest CSLAP lake

173 pixels fully or partly in the lake

Many mixed pixels

Still usable?

Image: 25th April 2019

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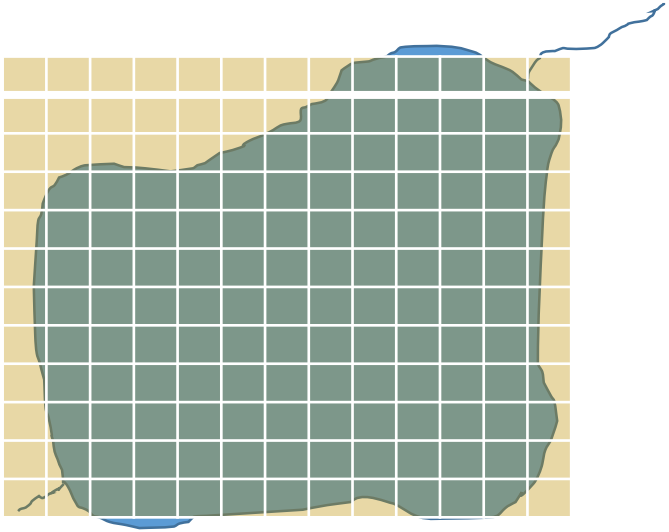
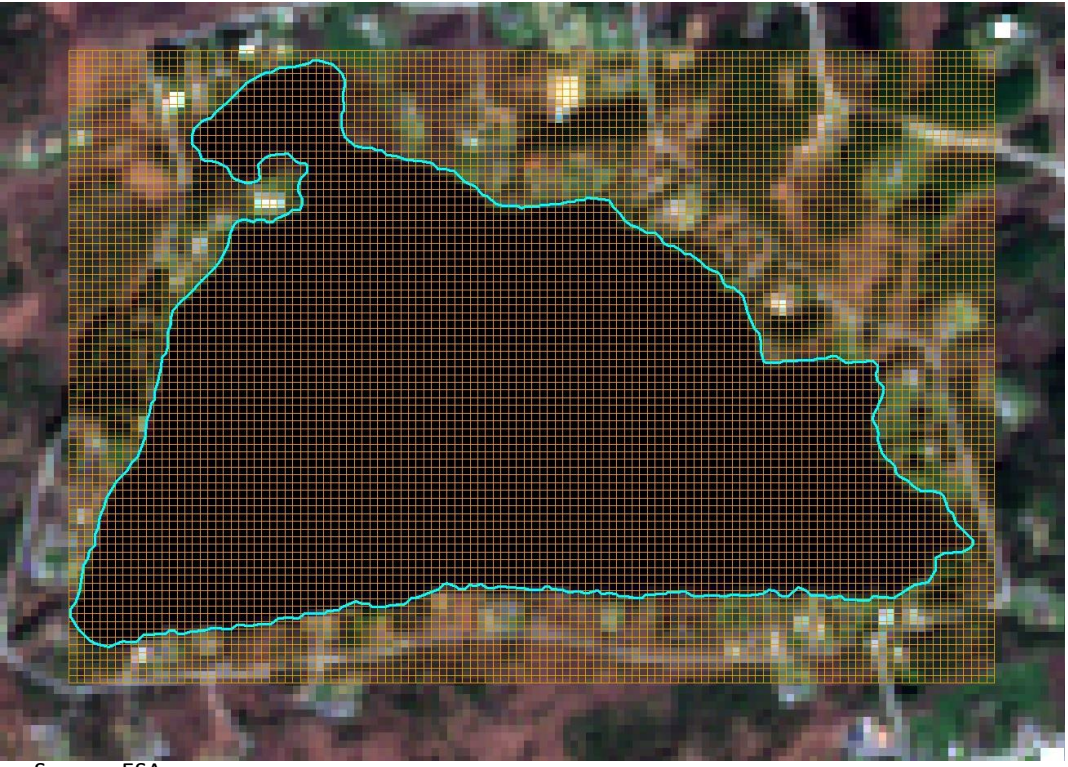
Pixel limitations - % per pixel

- Depending on lake shape, for each pixel to equal 1%, need 12x12 = 144 pixels per lake
- Equivalent to 14,400m² or 3½ acres



Pixel limitations - % per pixel



Source: ESA

E.g. Duane Lake

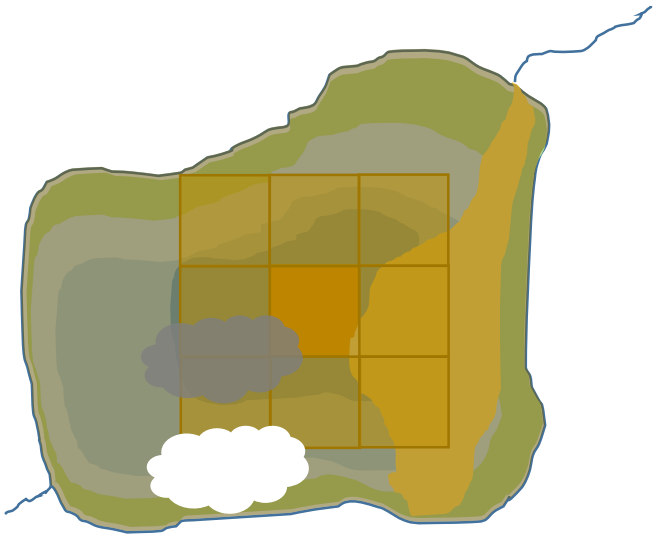
Many pixels, so each is less than 1% of lake surface

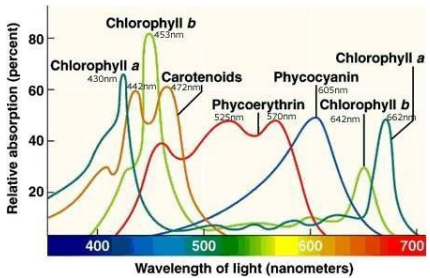
GREAT!

Lake limitations & interferences

- Visible bottoms:
  - Shallow lakes
  - Deeper lakes with very clear water
  - Macrophytes→

- Colored water →
- Sediment plumes →
- Opaque clouds, & shadows →
- Algae species mixture →
- Waves, glint
- Water vapor, aerosols, dust, cirrus cloud→





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Example interferences: atmosphere

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Example interferences

Owasco Lake Shallows
Landsat 8

Cayuga Lake Shallows
& macrophytes
Landsat 8

Source: ESA

Owasco Lake
Sediment Plume
Sentinel 2

Otisco Lake
Sediments
Landsat 8

Contrails & plane
Sentinel 2

Satellite Options

Satellite	Return period	Useful bands	Pixel size
Landsat 8*	16 days	RGB & IR	30m
Sentinel 2 A/B	5 days	RGB & IR	10m
Sentinel 3 A/B	13 days	RGB & Chl	300m
Terra/Modis	Daily	RGB & Chl	1000m
Commercial**	Various	RGB, pan	<1m

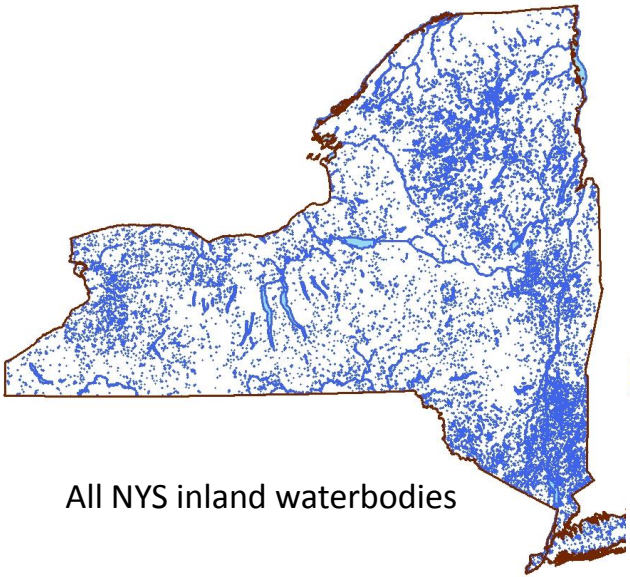
Selection is a compromise of all factors.

*Used by Baird on small number of lakes in NYS

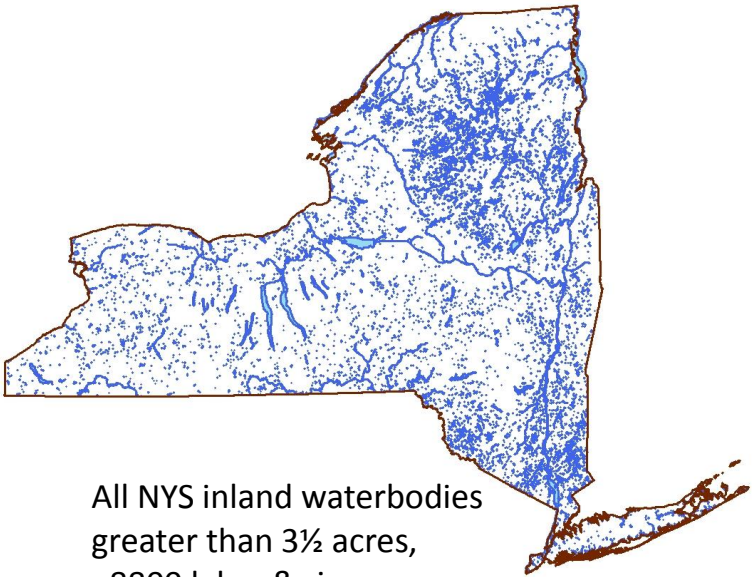
**$10 - $29 per km^2

Lakes imaged by the technique

With each 10x10m pixel representing at least 1% of the lake surface



All NYS inland waterbodies



All NYS inland waterbodies greater than 3½ acres, ≈8800 lakes & rivers

We chose Sentinel 2 A & B

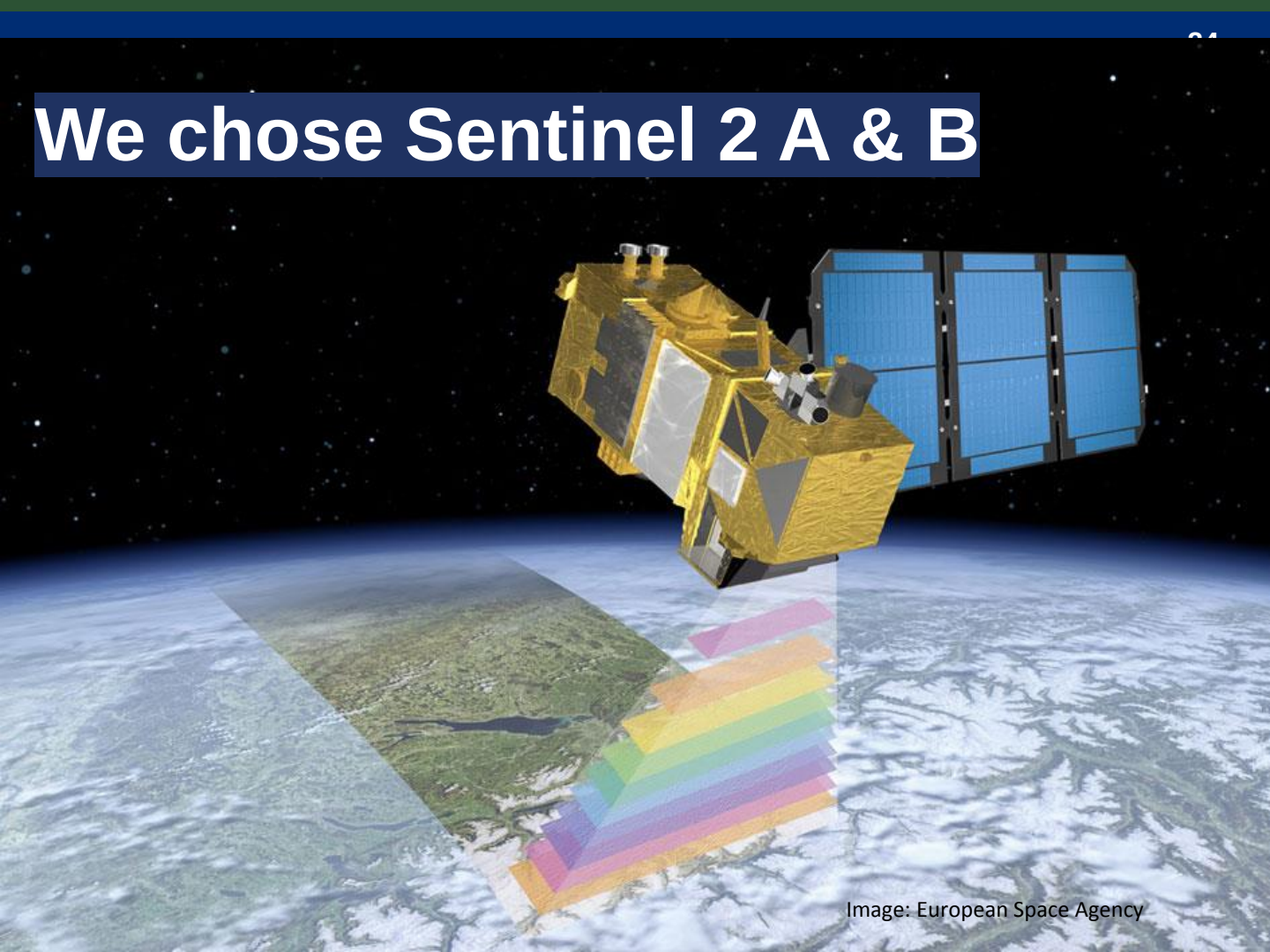


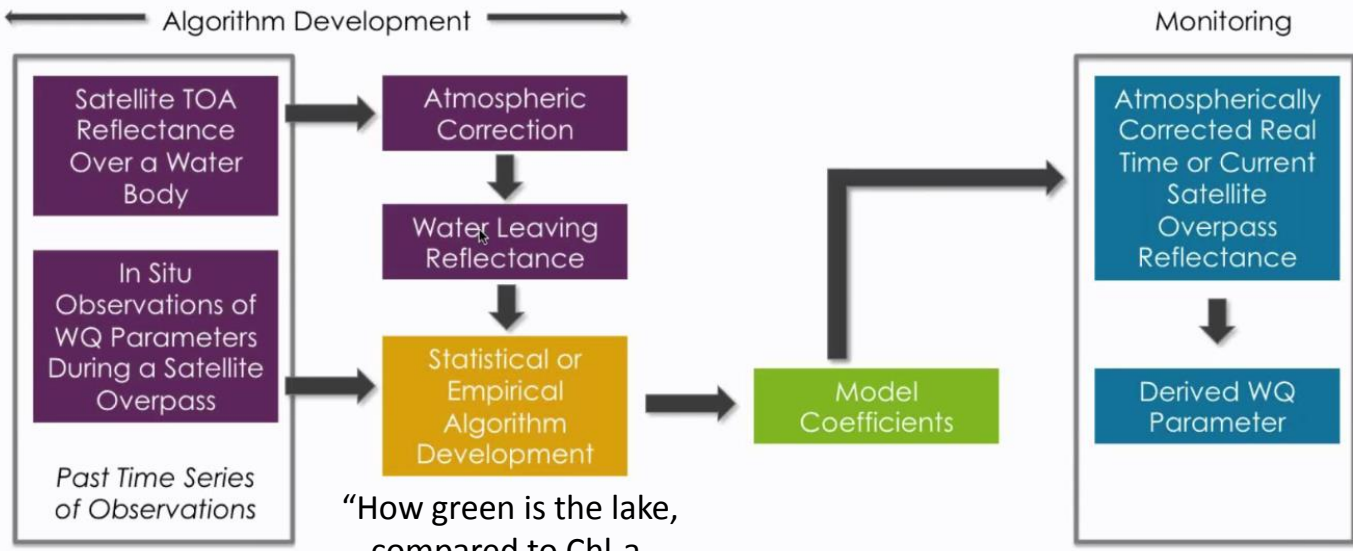
Image: European Space Agency

Pilot project in the Finger Lakes

From raw satellite Image…

Water Quality Parameters from Remote Sensing Observations

Quantitative Technique



"How green is the lake, compared to Chl-a concentration?" →

Source: NASA ARSET Training, September 2018

Pilot project - Sampled Pixels

- Used 2017 & 2018 CSLAP data
- Up to five points per lake, 8 times each summer
- Some features noted:
  - Patchy, probably ephemeral distribution
  - Relatively few images within 4 days of water samples *and* cloud free

Honeoye Lake

Image: ESA

n = 7

2017&18 Same Day

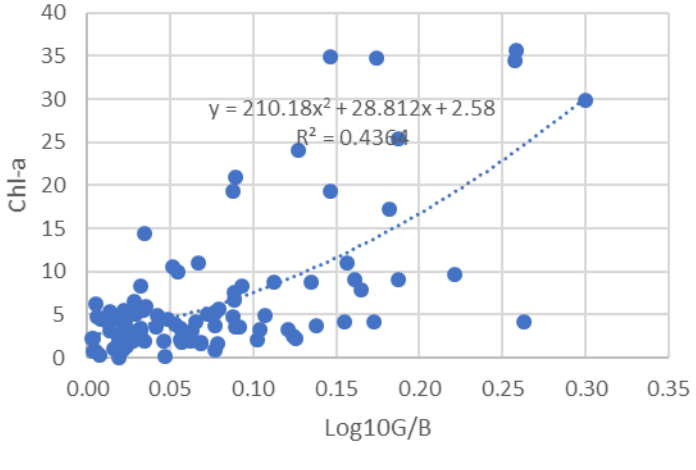
2017&18 ≤1 day delay

2017&18 ≤2 day delay

2017&18 ≤3 day delay

2017&18 ≤4 day delay

2017&18 ≤4+ day delay



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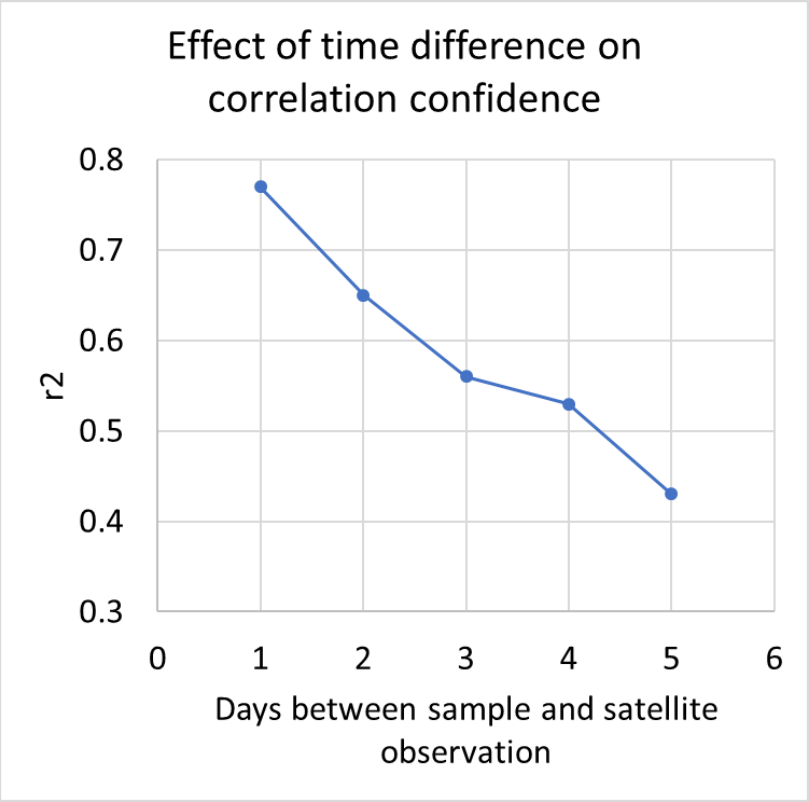
Effects of time difference



Pilot project - Algorithm development

There were 421 samples for Chl-a in 17&18

But selecting for:

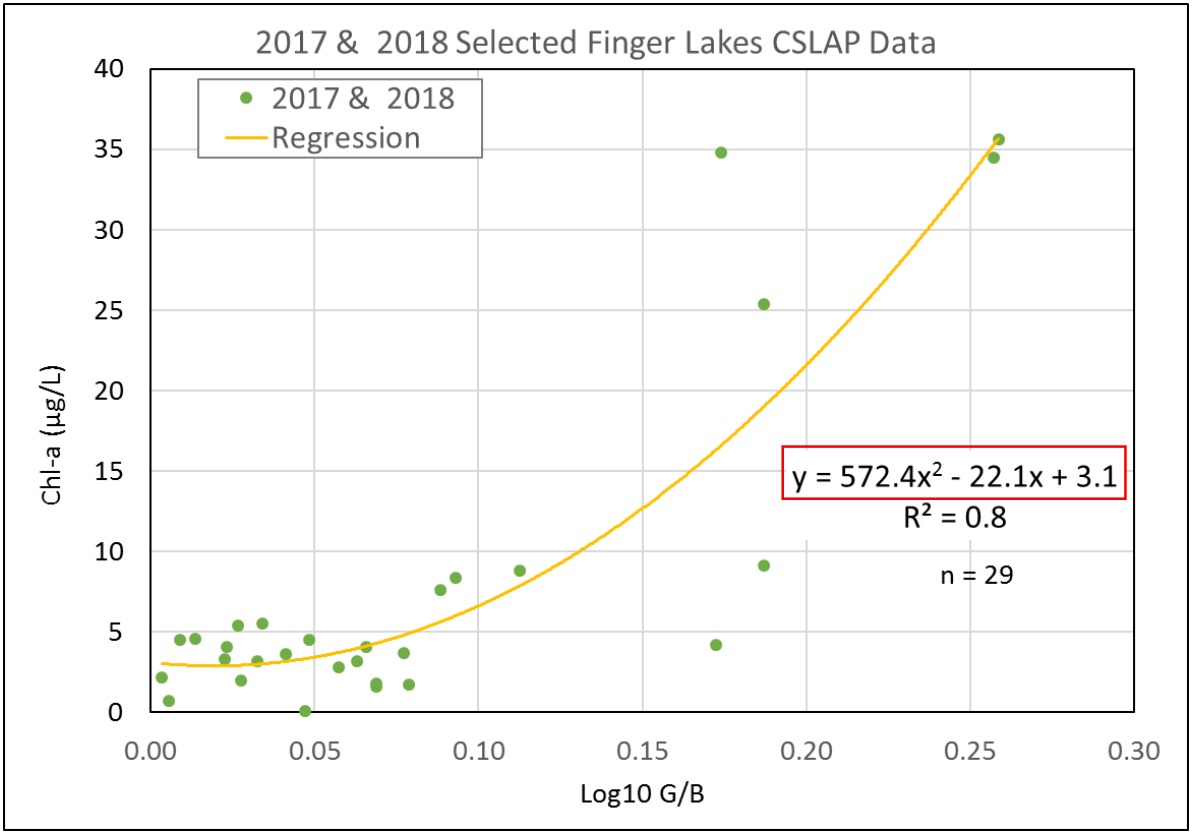
- less than 2 days delay
- no cloud interference

Only 29 data points are usable:

(only Keuka is missing)

Lake	# of samples
Cayuga	6
Honeoye	6
Otisco	4
Conesus	3
Owasco	3
Canadice	2
Seneca	2
Canandaigua	1
Hemlock	1
Skaneateles	1

Pilot project - Algorithm development



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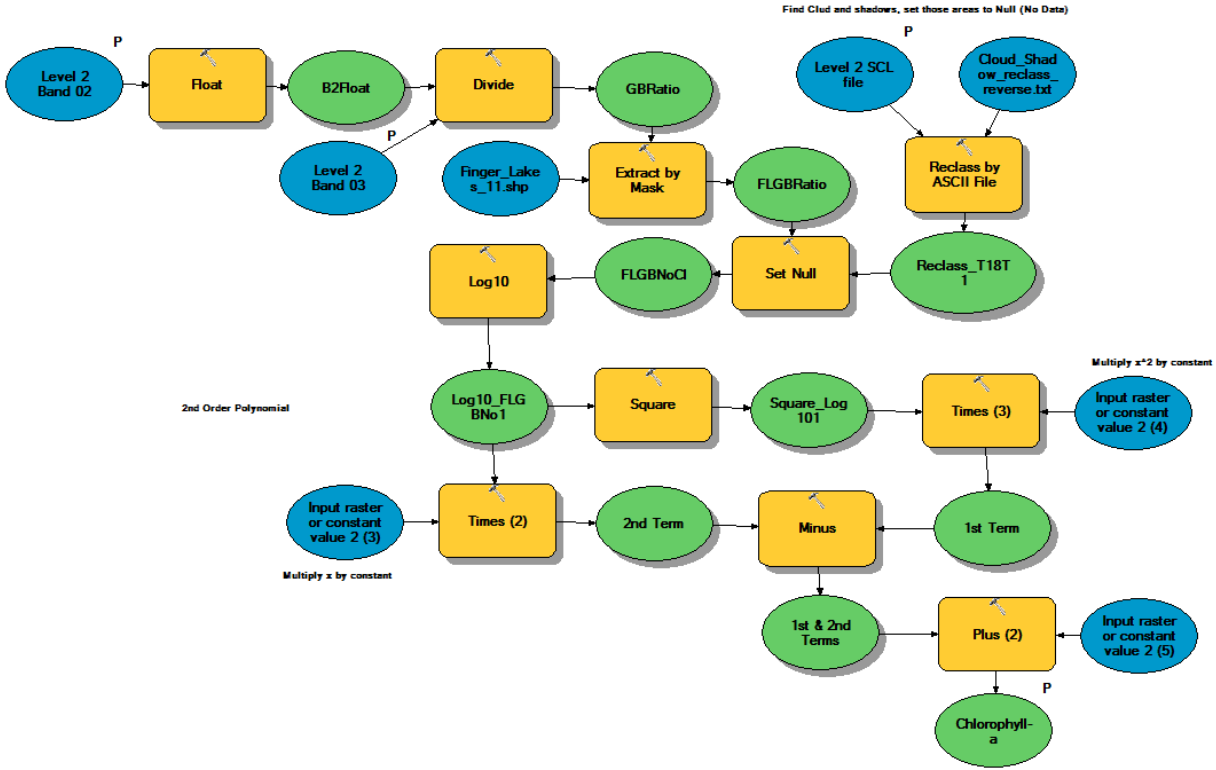
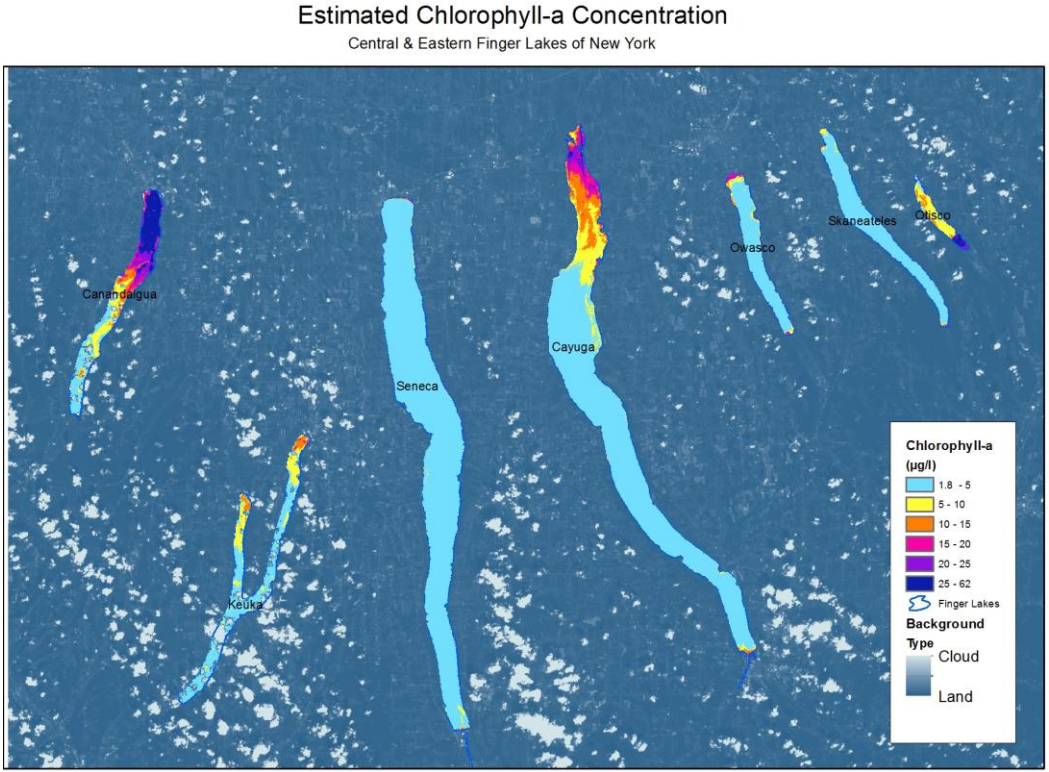
Pilot project - Geoprocessing model

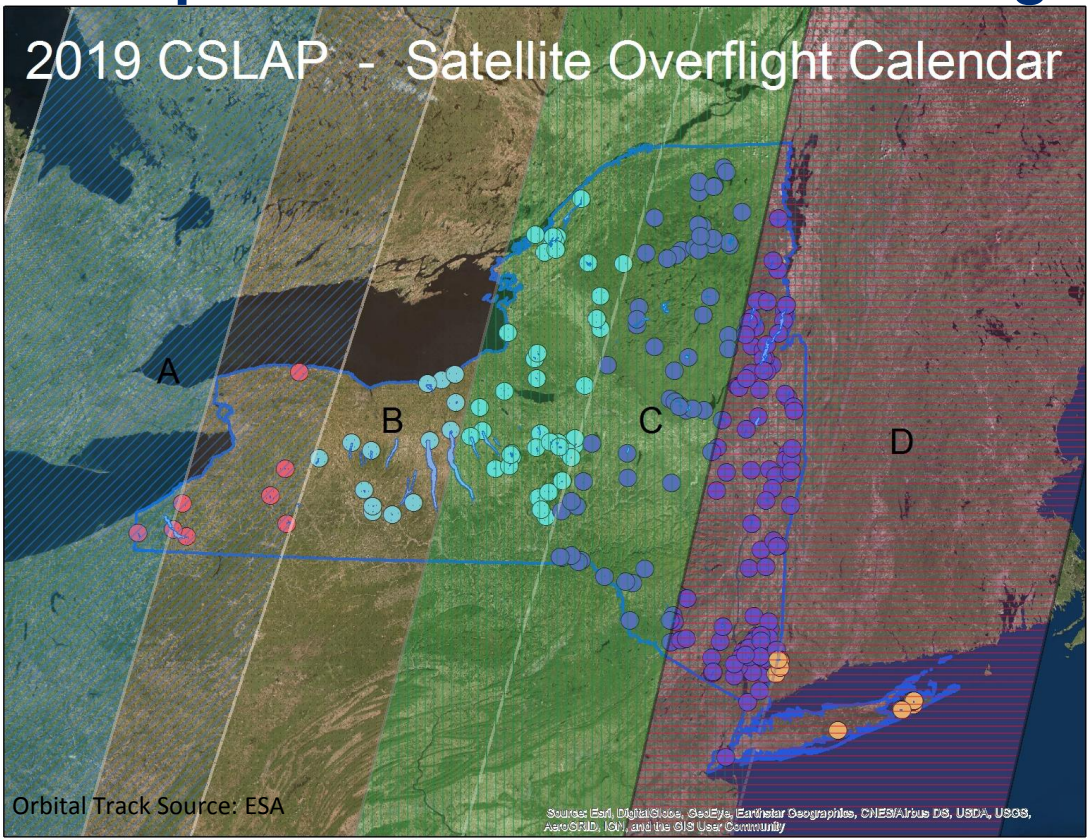


…To processed product



Next Steps

Next steps – CSLAP timed to overflights



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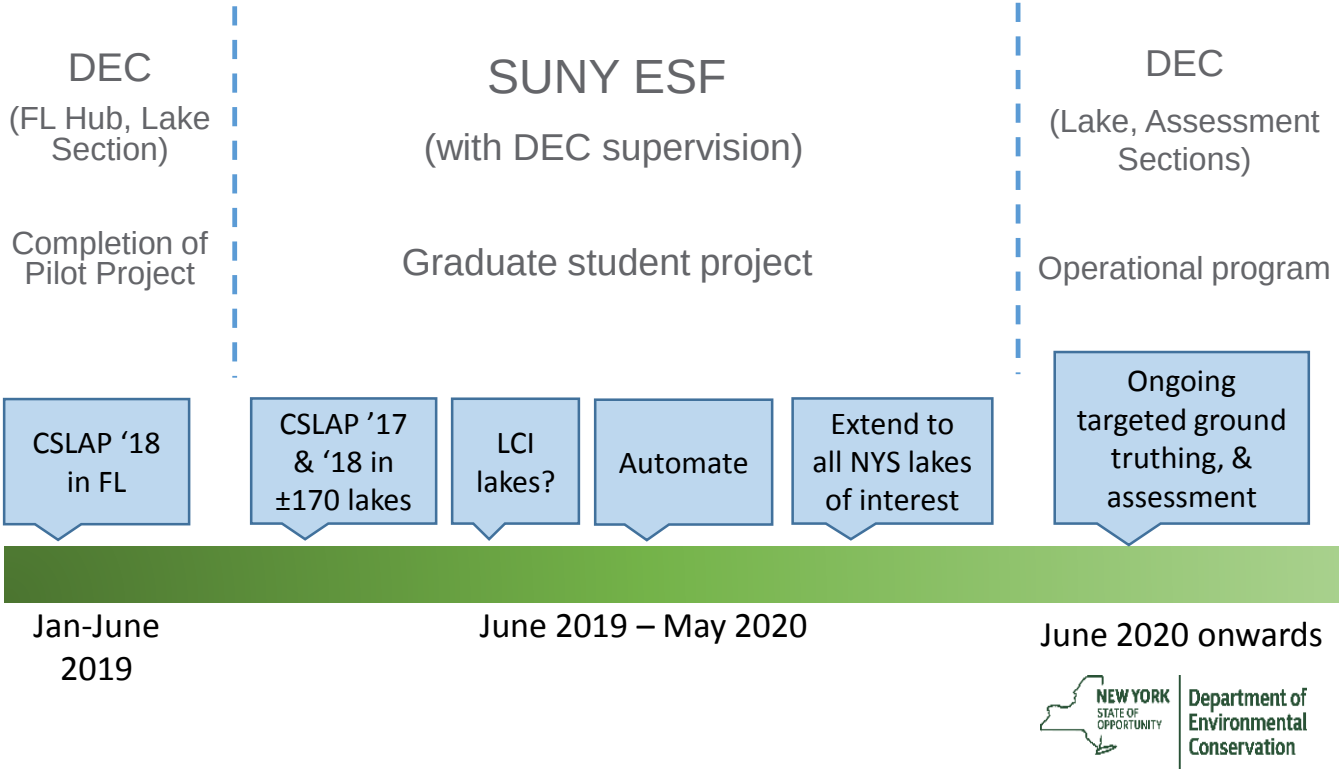
Next steps - Timeline



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Next steps - Training and Expertise needed

Find a graduate student, with these competences:

- GIS – graduate level
- Satellite Remote Sensing – u.grad level
- Limnology – u.grad level
- Java/python programming – graduate level

- MSc or M.Eng?
- Identify suitable supervisor & C'tee
- Funding

Thank You

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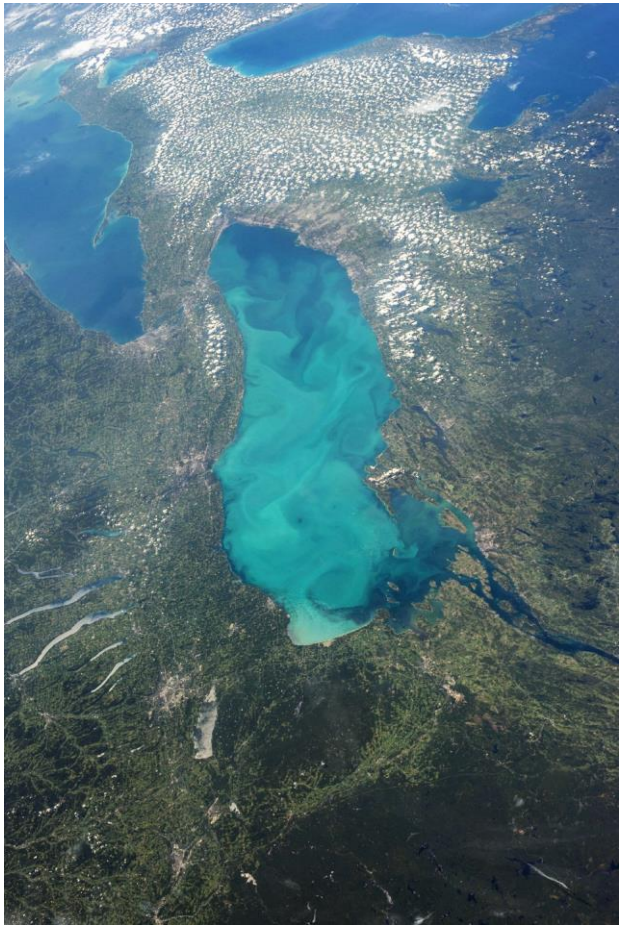
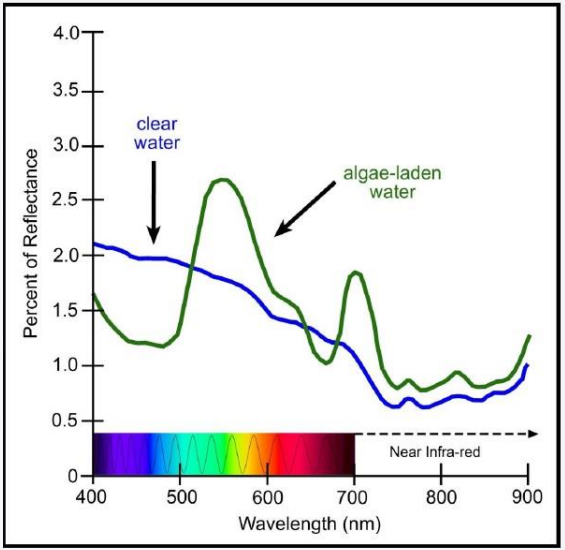


Image: NASA

Other possibilities



Percent reflectance of clear (blue) and algae-laden (green) water (data from Han, 1997).

Currently processed on Desktop PC
Try Cloud, e.g. Google Earth Engine?

Currently Blue\Green
Try Blue \ 'Red Edge'
Or more complex combinations?

Next steps - organization

DEC only

- Split duties, extended completion time
- Academic consultation
- Alignment with DEC priorities
- ‘Limited’ expertise within DEC

SUNY ESF Student

- Dedicated person, rapid once appointed
- Academic supervision
- DEC on supervisory c’tee, & funding the project
- Network of experts within ESF & wider SUNY

Lake sites used

Lake Site	# of samples
Honeoye 1	3
Honeoye 2	3
Owasco 1	3
Canadice 1	2
Cayuga 2	2
Cayuga 5	2
Conesus 1	2
Otisco 1	2
Otisco 2	2
Canandaigua 2	1
Cayuga 1	1
Cayuga 3	1
Conesus 2	1
Hemlock 1	1
Seneca 1	1
Seneca 2	1
Skaneateles 1	1

Next steps

1. Use 2018 CSLAP results for Finger Lakes
2. Use 2017/18 CSLAP results for all CSLAP lakes
3. Use LCI (& other DEC WQ data), expand to other lakes (& rivers?)
4. Develop general curves based on type, extend to all NYS waterbodies of interest
5. Targeted ground truthing (WQ sampling)
6. Automate download and GIS processing
7. Develop management stats & reporting