Modeling spatio-temporal variability of algal bloom using MODIS imagery of inland waters

C. Ratté-Fortin[1], K. Chokmani[1], A. El Alem[1]
claudie.ratte-fortin@ete.inrs.ca
[1]INRS–ETE, 490 rue de la Couronne, Québec, Qc, Canada, G1K 9A9

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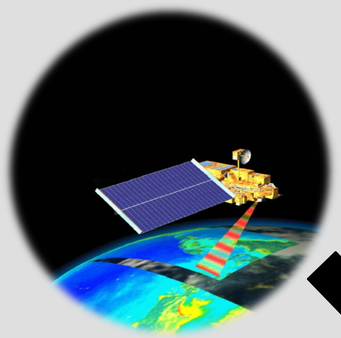
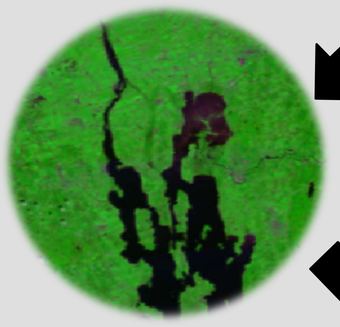
Abstract

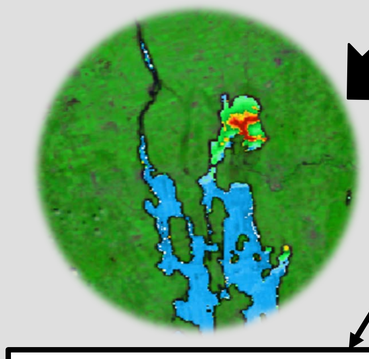
This study is part of a project aimed to monitor and assess past, present and future water quality in inland waters using MODIS imagery downscaled to 250 m spatial resolution (MODIS-D-250). The objectives of this study is:

- To develop a water bodies (inland, coastal, and open ocean) **cloud masking** based on a linear discriminant analysis algorithm using MODIS-D-250.
- To establish a **regional portrayal** of the harmful algal blooms (HABs) occurrence on Southern Quebec using a geospatial database including the **phenology features** of HABs (e.g. beginning, duration, intensity).
- To develop a statistical model which will **estimate the predisposition** of lakes in developing HABs according to their physiographic and climatic characteristics.

1-Proceeding from MODIS imagery to chl-a concentrations at 250 m spatial resolution







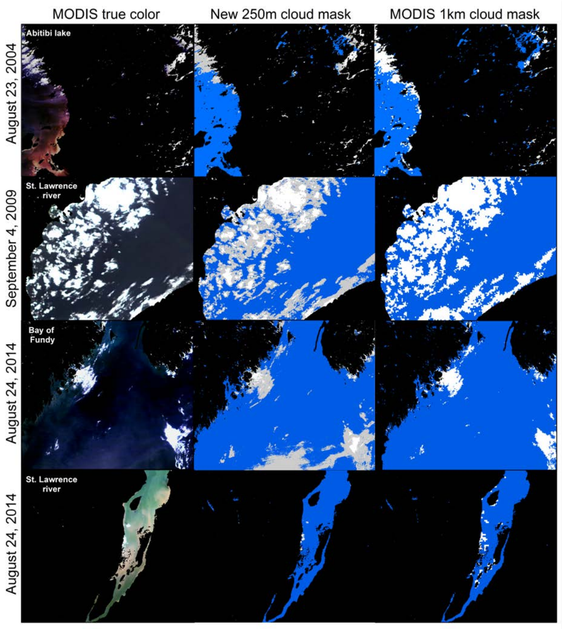
From 2000 to 2016…

①	**Downloading MODIS Level 1B product**	
②	**Pre-processing steps:** (1) Downscaling bands 3-7 from 500 m to 250 m spatial resolution (2) Re-projection (3) Atmospheric correction	Trishchenko (2006)
③	**Land mask:** Distinguishing water pixels from mixed (land-water) pixels	El Alem (2014)
④	**Cloud mask :** Detecting cloud/haze over water bodies containing optically active components	Ratté-Fortin (2017)
⑤	**Chl-a concentration:** Estimation at 250 m spatial resolution	El Alem (2014)

Quantitative validation: Monte-Carlo cross validation

		Observed					
		Water	Haze	Cloud	Total	Commission error	Success rate
Predicted	Water	696	0	0	696	0%	100%
	Haze	0	324	0	324	0%	100%
	Cloud	0	8	1184	1192	1%	99%
	Total	696	332	1184	2212		
	Omission error	0%	2%	0%			
	Success rate	100%	98%	100%			95% confidence interval of the mean
	Global success					99.4%	**99.6%** 99.8%
	Kappa					99.0%	**99.3%** 99.7%

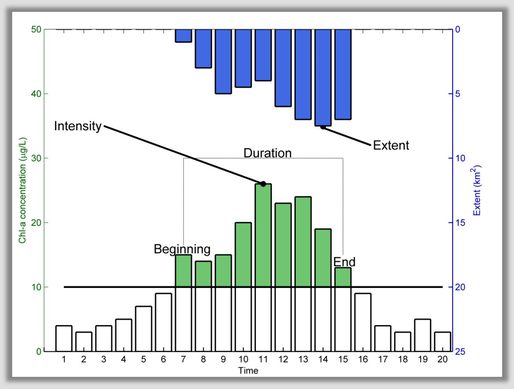
Qualitative validation: model applied on images



- A new cloud mask has been developed with an **improved resolution of 250 m**, leading to an increase of exploitable data in the context of water colour studies.
- The model shows a **better performance** than the **MODIS cloud mask** when it's applied on turbid waters, and particularly on highly turbid waters located at the edge of the urban area.
- The model shows a **low commission error** which is essential for an accurate algal blooms monitoring. Indeed, the presence of clouds/fog/aerosols affects the estimation of chl-a concentration.

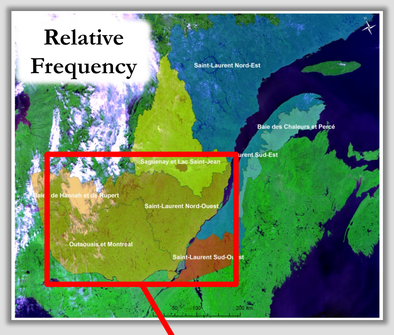
2-Defining phenological variables

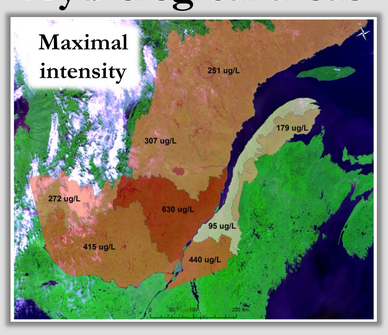
①	**Beginning:**	Threshold=$\frac{10\ \mu g}{L} \cong \frac{20\ 000\ cells}{mL}$ (WHO, MDDELCC)
②	**Duration**	Number of days between the beginning and the ending day.
③	**Intensity:**	Maximal concentration value between beginning day and ending day.
④	**Extent:**	Maximal Extent between beginning day and ending day.
⑤	**Frequency:**	Number of bloom episode per year.

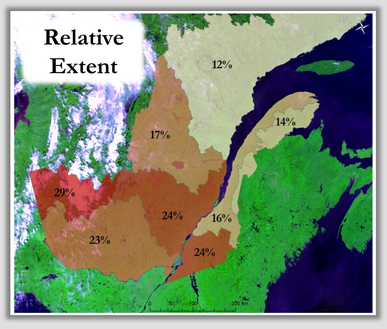


3-Portrayal of HABs in southern Quebec

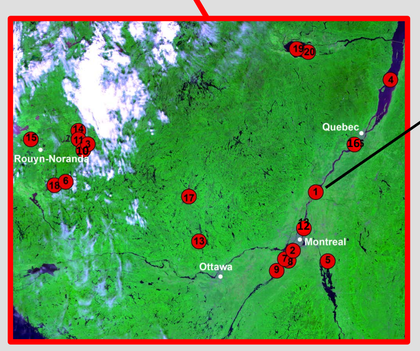
Hydrological areas







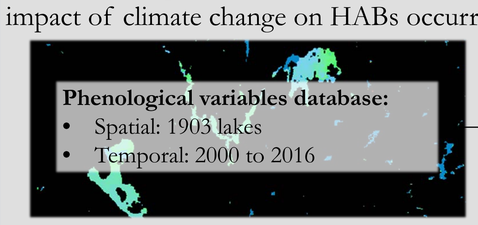
Top 20 observable lakes with bloom occurrence



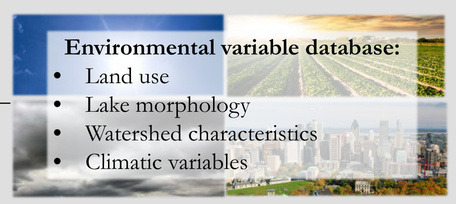
	Name	Frequency (days)	Mean intensity (ug/L)	Max intensity (ug/L)	Mean extent (%)	Max extent (%)
1	Lac Saint-Pierre	372	18	5554	78%	81%
2	Lac Saint-Louis	372	14	834	67%	75%
3	Lac De Montigny	340	26	487	66%	68%
4	Fleuve Saint-Laurent	340	19	2468	71%	75%
5	Baie Missisquoi	339	19	1223	63%	67%
6	Lac Simard	332	18	2490	71%	74%
7	Fleuve Saint-Laurent	317	16	81	46%	53%
8	Canal de Beauharnois	314	19	133	53%	58%
9	Lac Saint-François	313	15	1163	19%	23%
10	Lac Fournière	311	21	309	65%	71%
11	Lac Malartic	293	24	541	69%	73%
12	Fleuve Saint-Laurent	290	16	434	75%	80%
13	Lac Heney	286	25	149	58%	65%
14	Lac La Motte	270	23	42	84%	87%
15	Lac Duparquet	269	21	189	72%	75%
16	Fleuve Saint-Laurent	269	18	4879	83%	85%
17	Réservoir Baskatong	268	44	5066	6%	8%
18	Lac Gaboury	263	29	97	81%	84%
19	Lac Saint-Jean	257	31	2224	1%	1%
20	La Belle Rivière	256	18	28	76%	81%

4-Links between HABs and physiographic and climatic characteristics ?

A statistical model (copulas) will be developed to analyze and describe the **relations** between **phenology features** (e.g. beginning, frequency, duration and intensity) and **climatic, physiographic and anthropologic characteristics** in connection with HAB's development (e.g. temperature, precipitation, lake depth, watershed area, agricultural land uses). Through the development of the model, **(i)** we will be able to estimate the predisposition of HABs on a lake based on environmental characteristics on the watershed, **(ii)** we will improve our knowledge about the impact of these anthropic perturbations, and **(iii)** evaluate the impact of climate change on HABs occurrence.



Multivariate frequency analysis



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