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# **Remote Sensing & Environment Canada's Responsibility to Monitor Canadian Inland Water Quality**

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**Globalakes**

**Stirling, December 2012**



# Canada's Inland Waters

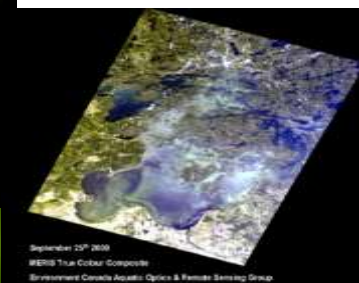
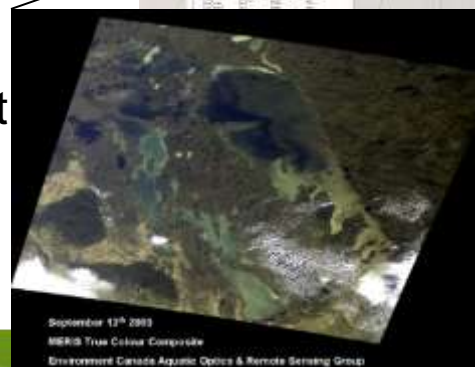
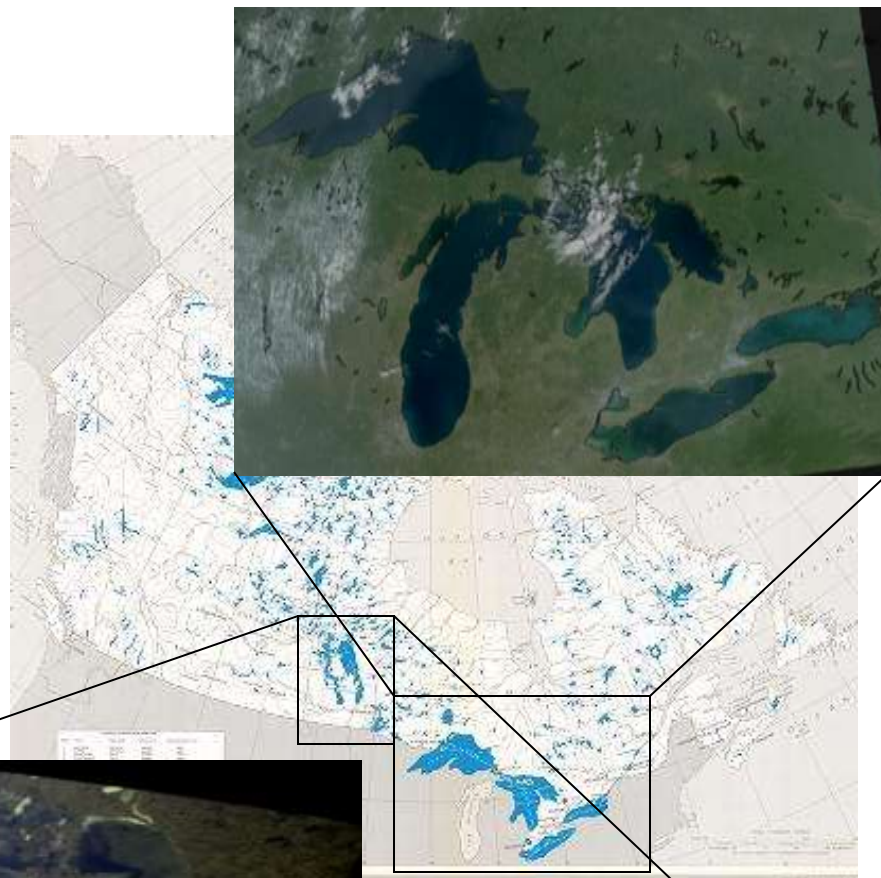
Fresh water covers about 8% of Canada's surface area

> 30,000 lakes 3-99 sq-km

565 lakes > 100 sq-km

Highly variable lake properties –  
oligotrophic → eutrophic → highly  
turbid → DOC loaded → whiting  
events → glacier-fed lakes

Research/product development  
focuses on Great Lakes, Lake  
Winnipeg, Lake of the Woods.



# EC's Inland Water Quality Obligations

- Canada Water Act (1970), Canadian Environmental Protection Act (1999)
- GLWQA - Signed 1972, To restore & enhance water quality in the Great lakes by improving water chemistry through control of point sources of pollution. Amended in Sept 2012.
- Introduction of Areas of Concern, Remedial Action Plans, Lakewide Management Plans for all 5 lakes - Key governance mechanisms involving compilation & analysis of research & monitoring, determining current & future impairments, assessing current efforts and obtaining commitment to implement additional actions
- Canada–Ontario Agreement: Federal-provincial agreement that supports the restoration, protection & conservation of the Great Lakes Basin Ecosystem



# Remote Sensing and Water Quality Monitoring of Inland Waters

- Monitoring long term trends in water quality in response to: invasive species, nutrient loadings, implemented management practices, and physical/climatic variables
- Monitoring dynamic processes in NRT (early detection of potential HABs)
- Identifying and monitoring areas of potential water quality concern
- Observations in support of logistically difficult in situ monitoring (e.g. winter bloom monitoring, remote locations – Lake of the Woods)

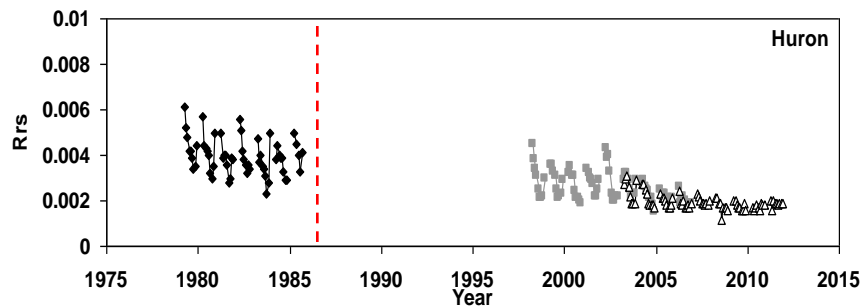
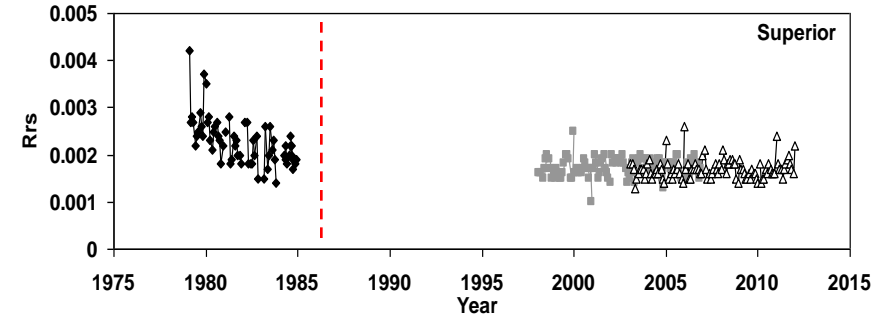
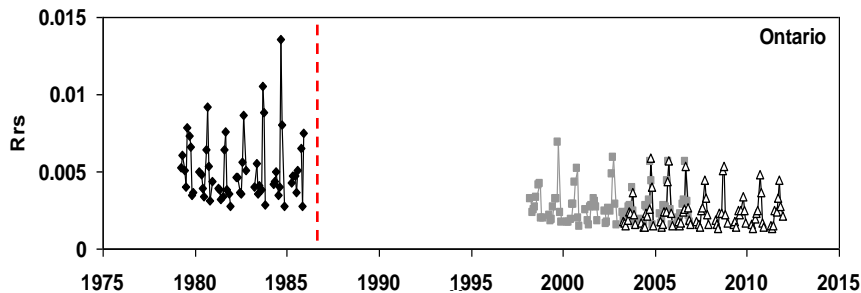
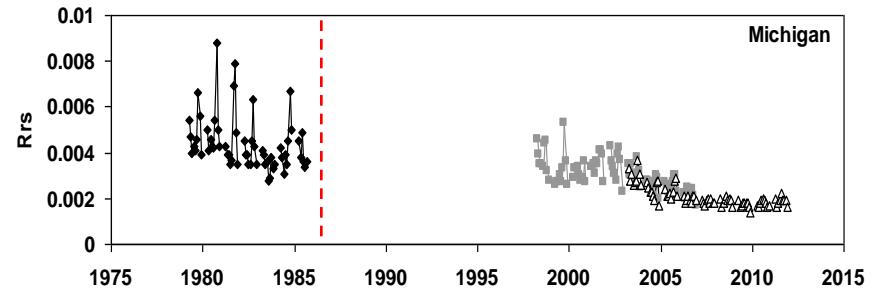
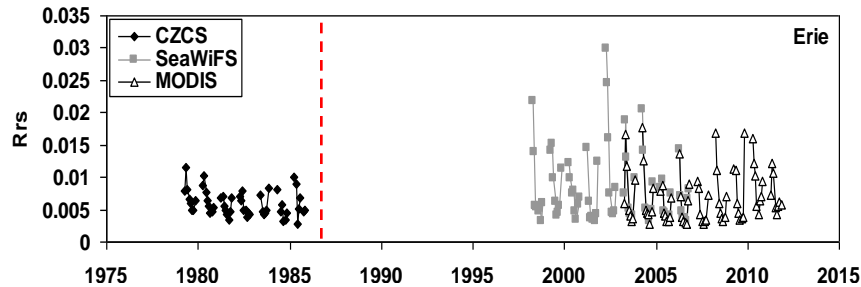


# EC's aquatic colour image processing capabilities

- Fully autonomous NRT MODIS processing for Great Lakes – producing daily True Colour, SST, water clarity, mineral sediments and chlorophyll products.
- Archive monthly CZCS, SeaWiFS, MODIS imagery for the Great Lakes and Lake Winnipeg
- MERIS archive (MCI) for algal bloom monitoring of Lake Winnipeg, Lake of the Woods, and Lake Erie
- Exploring HICO hyper-spectral imagery for bloom composition discrimination



# Monitoring Long-term Trends in Great Lakes Water Clarity



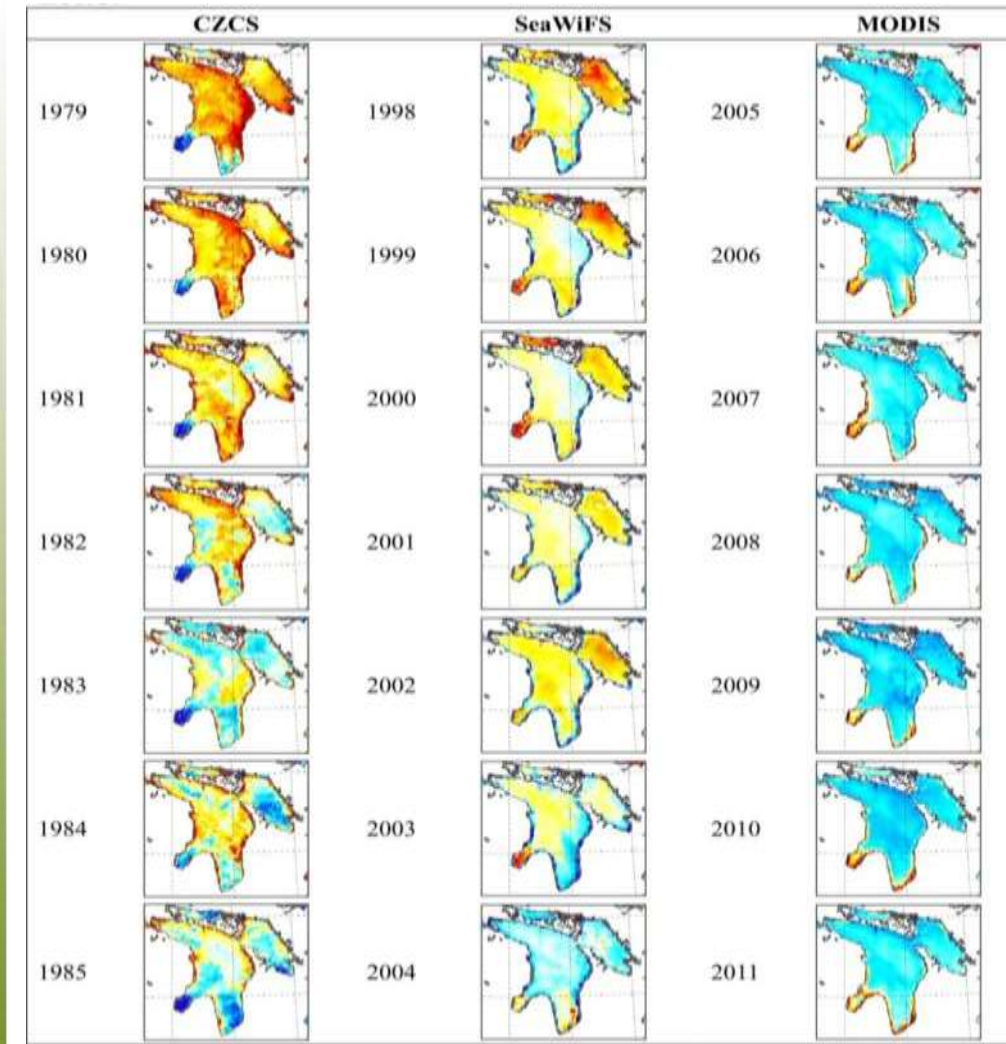
Last amendment of GLWQA,  
1987

Zebra Mussels first found in the  
Great Lakes, 1987





# Mapping Water Clarity Change – Lake Huron



Dramatic decreases in offshore Rrs

Notable increases in near-shore Rrs (e.g. Saginaw Bay, southern shores)

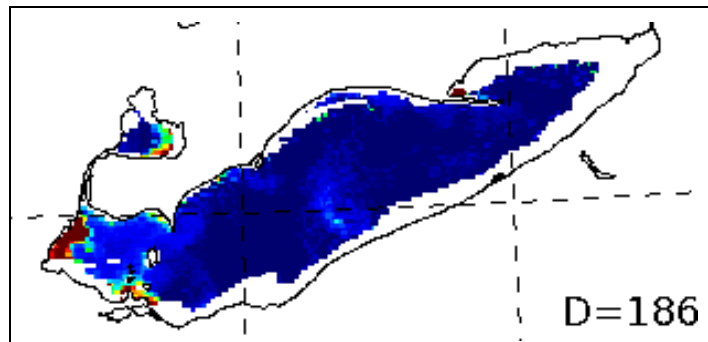
Annual Rrs550 Anomalies



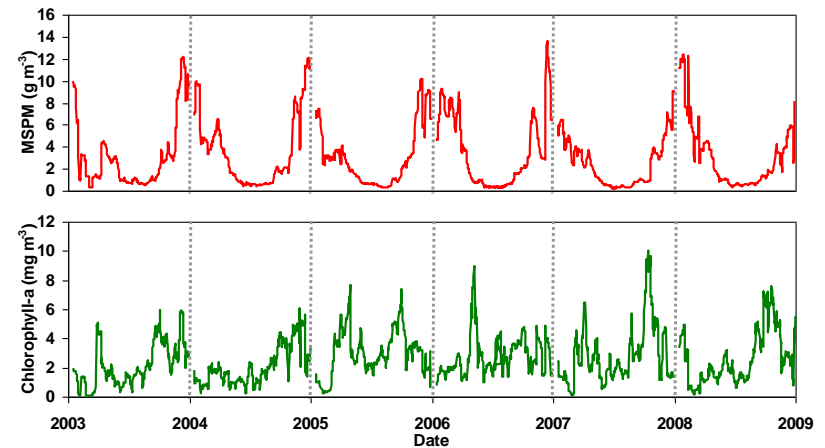
# Extracting mineral and algal turbidity using Red/NIR wavelengths

Inverse modelling of MODIS bands 667 and 748 to simultaneously extract mineral and algal concentrations in Lake Erie.

Independent of DOM & can neglect bottom reflectance but only really appropriate to turbid/productive waters



Algal bloom evolution  
Lake Erie, 2010

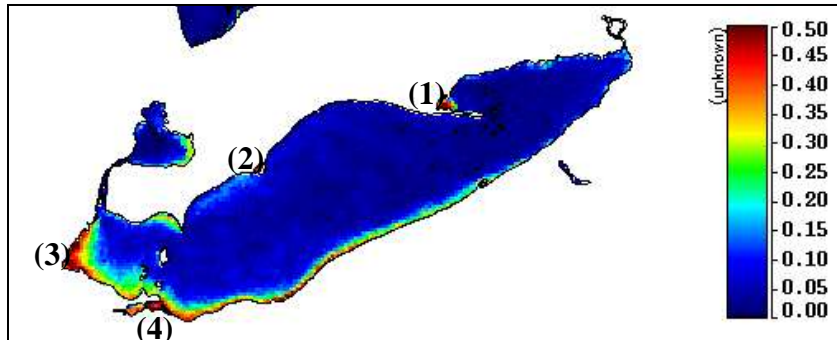


Distinct seasonal cycles of MSPM and CHLA



# Identifying Areas of Potential WQ Concern

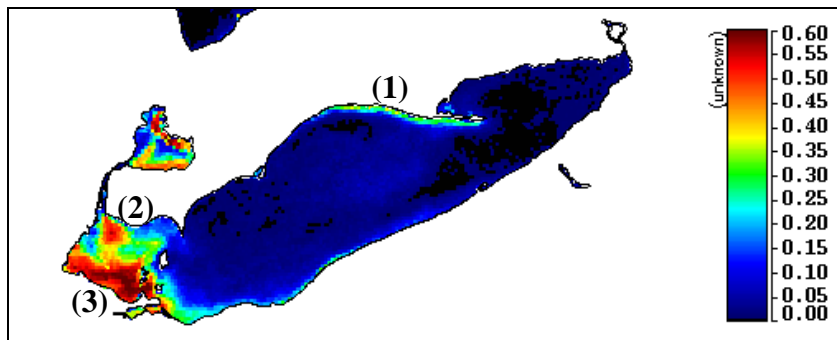
## Chlorophyll



# days each pixel concentration is within top 10% of lake-wide concentrations.

Created from > 2000 images

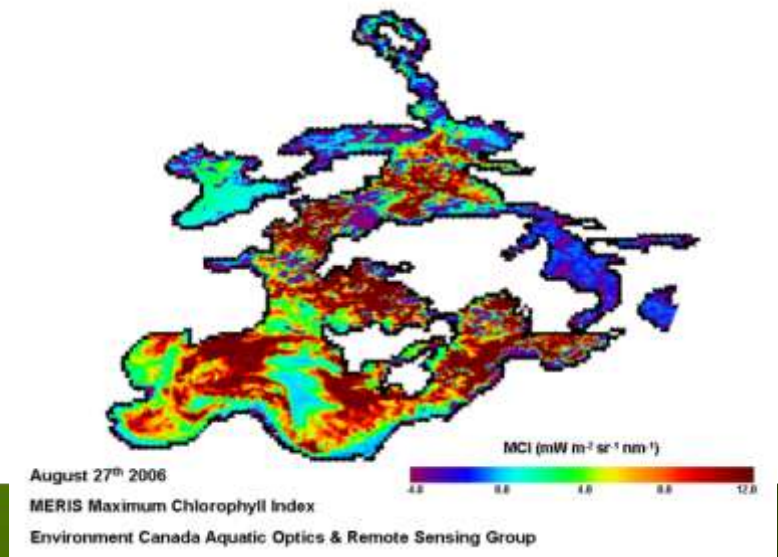
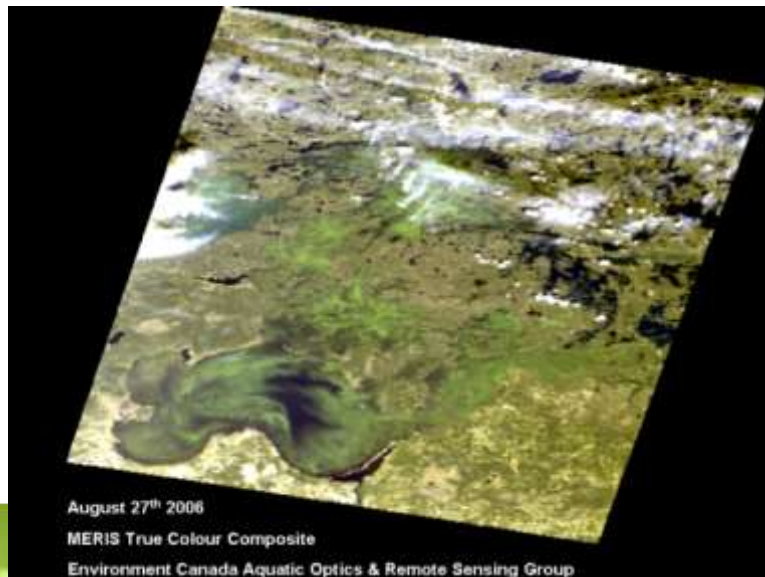
## MSPM



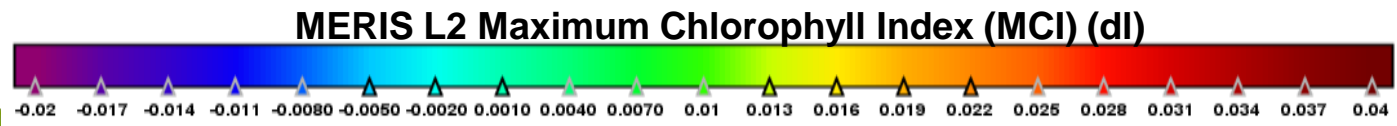
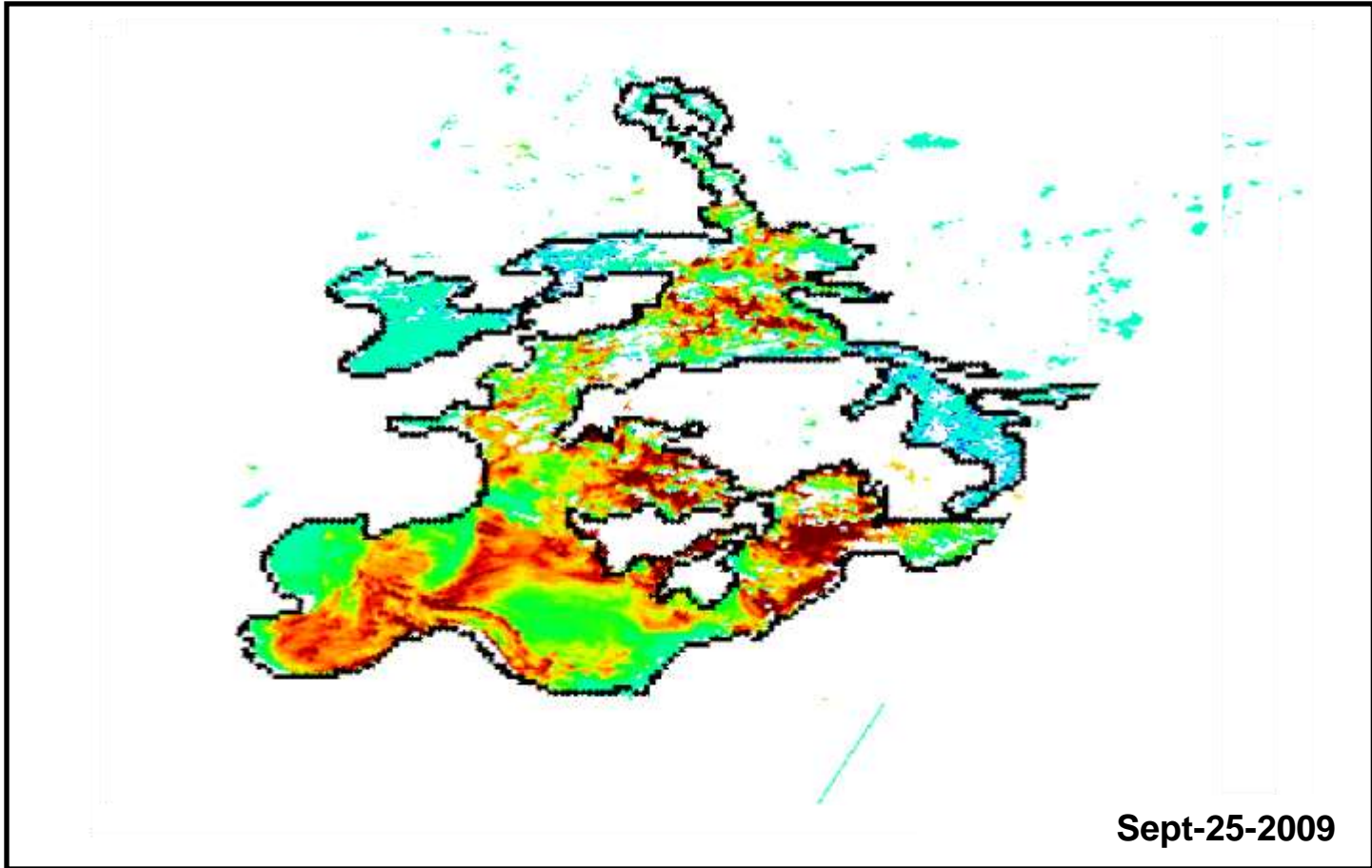
Provides indication of areas with persistently elevated concentrations for identification of potential areas of recurring water quality concern.

# MERIS Application to Eutrophic Waters

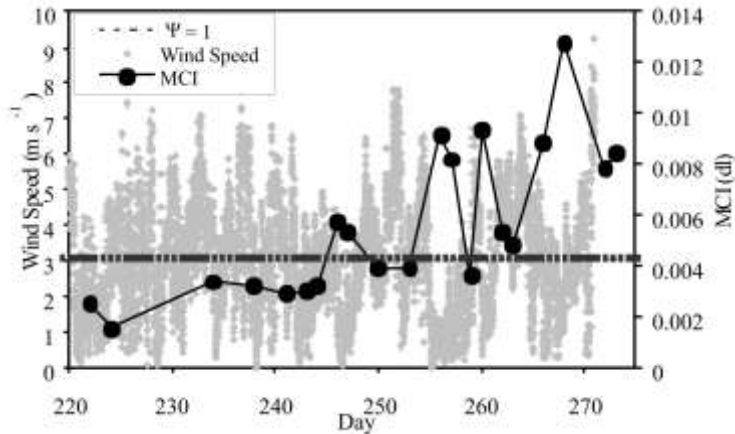
- Using MERIS MCI to monitor intense cyanobacteria blooms in Lake of the Woods and Lake Winnipeg
- Chlorophyll concentrations up to  $300 \mu\text{g L}^{-1}$ , with very high DOC ( $a_{\text{CDOM}} \sim 2 - 3 \text{ m}^{-1}$ ) - all MERIS Chl retrievals fail
- Strong agreement between MCI and in situ Chl



# Monitoring Dynamic Bloom Events



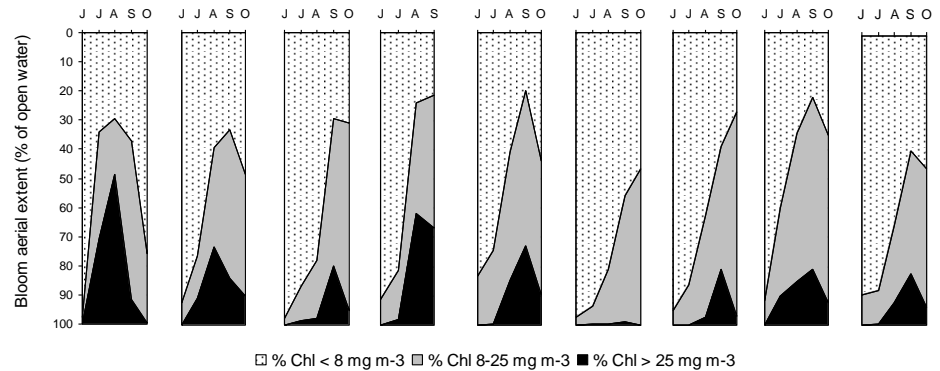
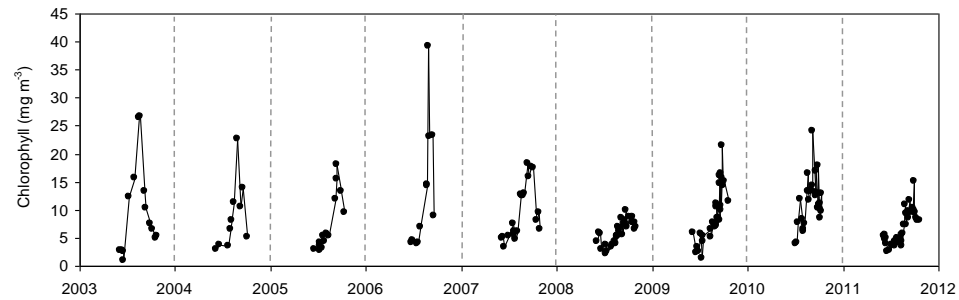
# Bloom Response Physical/Climatic Variables



Monitoring lake trophic status

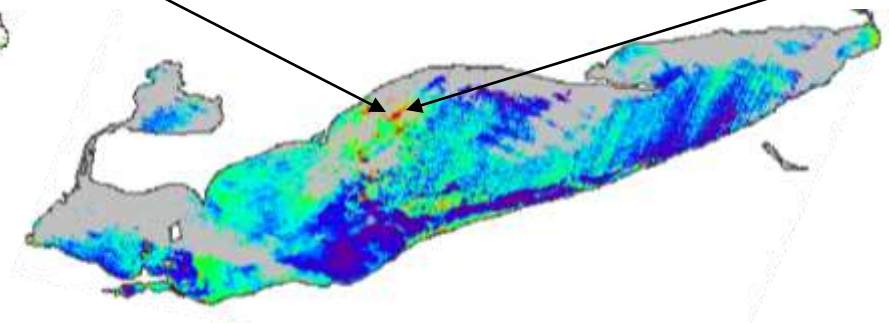
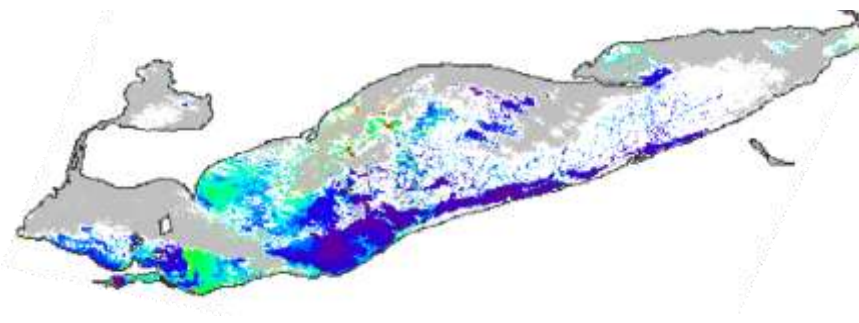
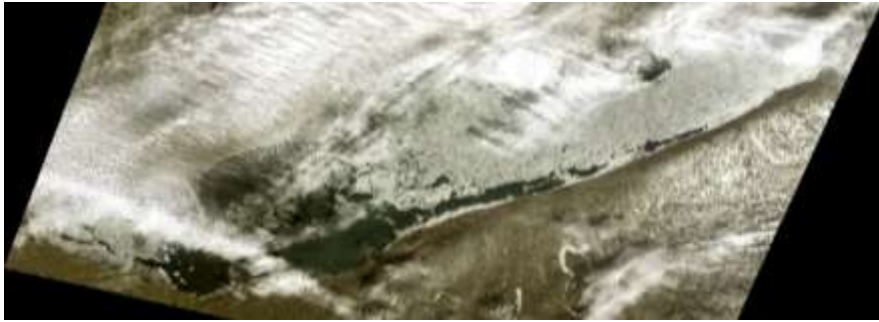
Relating timing, intensity and extent of blooms to climate variables and loadings

Evidence of repeated mixing/re-surfacing of bloom during wind events on the lake





# Winter Diatom Blooms on Lake Erie

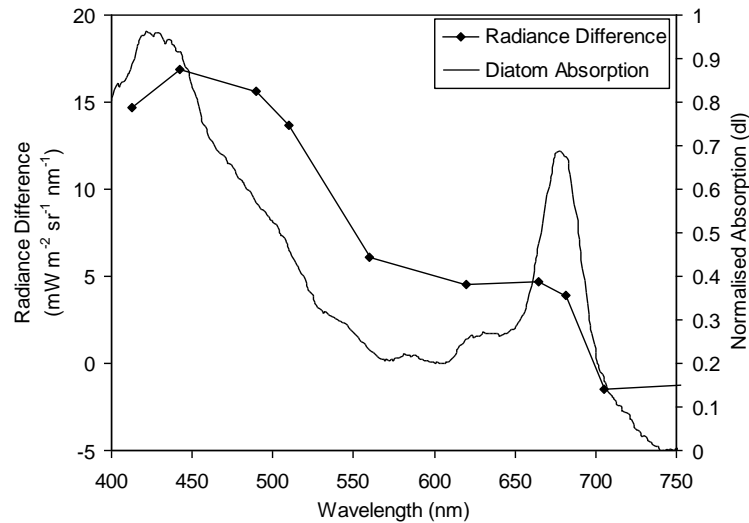


- Winter blooms of Diatom *Aulacoseira* on Lake Erie with chlorophyll concentrations up to  $100 \mu\text{g L}^{-1}$
- L1 MCI detects blooms within and surrounding surface ice



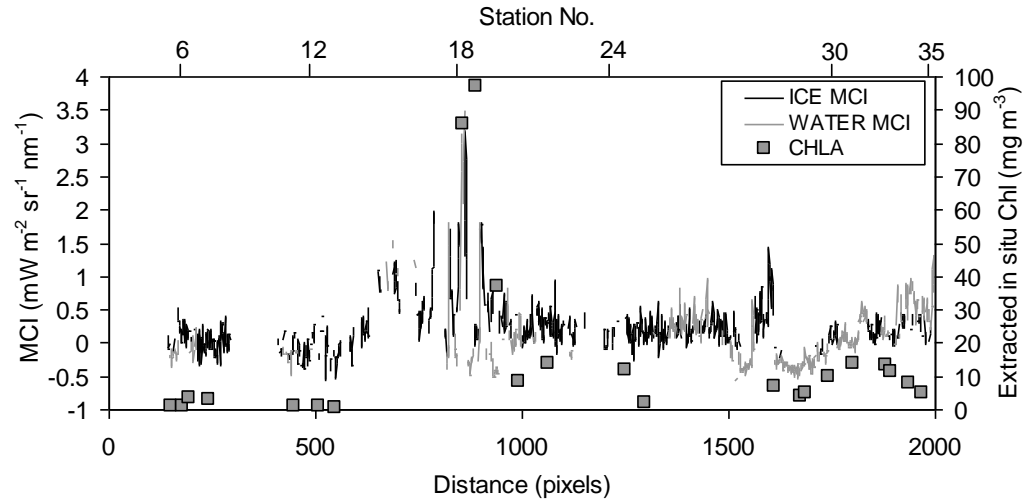


# Winter Diatom Blooms on Lake Erie



Subtracting clean ice signal produces radiance in agreement with absorption spectrum of chlorophyll-a

Location of blooms within ice in agreement with in situ chlorophyll determinations along cruise track



# Summary

- Aquatic colour imagery used extensively in meeting EC's Great Lakes water quality monitoring obligations:
  - Recording long term lake-wide conditions (through simple reflectance-clarity trends)
  - Examining recurring water quality issues such as algal blooms and mineral erosion
  - Monitoring in NRT algal bloom occurrences in remote or logistically difficult monitoring locations
- Allows for prompt detection and reporting of bloom occurrences, monitoring of lake trophic status, determine effectiveness of management practices, effects of invasive species, identify AOCs

