SYSTEM OF ENVIRONMENTAL ECONOMIC ACCOUNTING
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Water Accounts and Earth Observation

Statistics Canada

Delivering insight through data, for a better Canada

Table of content

- Water Asset Accounts and EO at Statistics Canada

- Considerations in the use of EO for water accounting

What is Earth Observation?

Earth Observation is the gathering of information about Earth's physical, chemical and biological systems using satellites, airborne, waterborne and earth-based (in situ) sensors. It involves monitoring and assessing the status and changes in natural and man made environments. It comes from sources that are :

1. In-situ
   - Stream gauges, air quality stations, weather station, buoy, etc
2. Airborne
   - Aerial photography, LIDAR, etc
3. Space-borne
   - Optical, radar, etc

Water asset account in Canada

1. Main impetus for the creation of the water asset account was to first provide a measure of the stock of **renewable freshwater resources.**
    - Currently working to add other aspects of the water budget (precipitation, evapotranspiration, total water stocks)

2. These estimates are an important element of Statistics Canada's suite of data on natural capital.
    - Integrated data and regular reporting on trends in freshwater is a growing concern worldwide

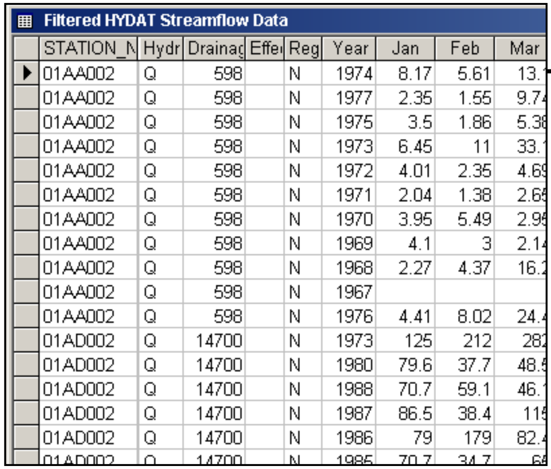
EO is a requirement to produce a water asset account

1. The most likely data source is stream gauging data for volume
   1. But some argue that this can be done using satellite data
   2. Certainly many aspects of the water budget can be informed by satellite data

2. NSO require new data streams and computing technologies:
   1. Satellite earth observation can provide internationally comparable data
   2. Satellite earth observation is important for validation of other data
   3. “In-situ” earth observation and In-situ knowledge are also required.
   4. “Advanced” computing environments and skills are required to handle the new data news
   5. Global data may be freely available, but a) are they good enough? and b) can they be integrated properly in a timely manner?

Overview of methodology

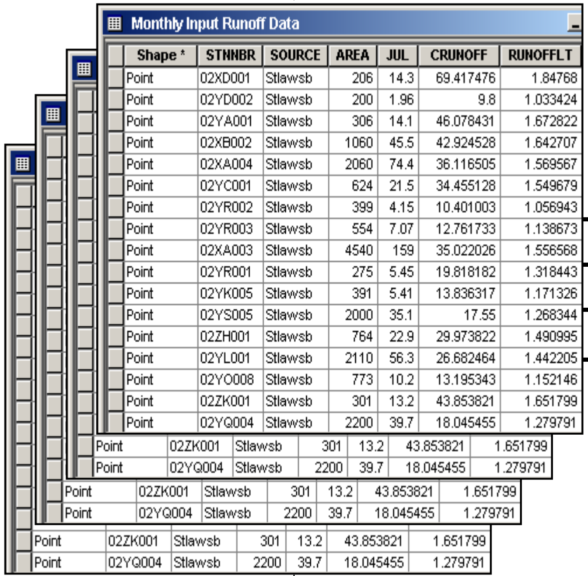
Filter HYDAT streamflow data



Filtered HYDAT Streamflow Data

STATION_N	Hydr	Drainag	Effe	Reg	Year	Jan	Feb	Mar
01AA002	Q	598		N	1974	8.17	5.61	13.
01AA002	Q	598		N	1977	2.35	1.55	9.7
01AA002	Q	598		N	1975	3.5	1.86	5.3
01AA002	Q	598		N	1973	6.45	11	33.
01AA002	Q	598		N	1972	4.01	2.35	4.6
01AA002	Q	598		N	1971	2.04	1.38	2.6
01AA002	Q	598		N	1970	3.95	5.49	2.9
01AA002	Q	598		N	1969	4.1	3	2.1
01AA002	Q	598		N	1968	2.27	4.37	16.
01AA002	Q	598		N	1967			
01AA002	Q	598		N	1976	4.41	8.02	24.
01AD002	Q	14700		N	1973	125	212	28
01AD002	Q	14700		N	1980	79.6	37.7	48.
01AD002	Q	14700		N	1988	70.7	59.1	46.
01AD002	Q	14700		N	1987	86.5	38.4	11
01AD002	Q	14700		N	1986	79	179	82.
01AD002	Q	14700		N	1985	70.7	34.7	6

Derive monthly runoff values



Monthly Input Runoff Data

Shape *	STNNBR	SOURCE	AREA	JUL	CRUNOFF	RUNOFFLT
Point	02XD001	Stlawsb	206	14.3	69.417476	1.84768
Point	02YD002	Stlawsb	200	1.96	9.8	1.033424
Point	02YA001	Stlawsb	306	14.1	46.078431	1.672822
Point	02XB002	Stlawsb	1060	45.5	42.924528	1.642707
Point	02XA004	Stlawsb	2060	74.4	36.116505	1.569567
Point	02YC001	Stlawsb	624	21.5	34.455128	1.549679
Point	02YR002	Stlawsb	399	4.15	10.401003	1.056943
Point	02YR003	Stlawsb	554	7.07	12.761733	1.138673
Point	02XA003	Stlawsb	4540	159	35.022026	1.556568
Point	02YR001	Stlawsb	275	5.45	19.818182	1.318443
Point	02YK005	Stlawsb	391	5.41	13.836317	1.171326
Point	02YS005	Stlawsb	2000	35.1	17.55	1.268344
Point	02ZH001	Stlawsb	764	22.9	29.973822	1.490995
Point	02YL001	Stlawsb	2110	56.3	26.682464	1.442205
Point	02YO008	Stlawsb	773	10.2	13.195343	1.152146
Point	02ZK001	Stlawsb	301	13.2	43.853821	1.651799
Point	02YQ004	Stlawsb	2200	39.7	18.045455	1.279791

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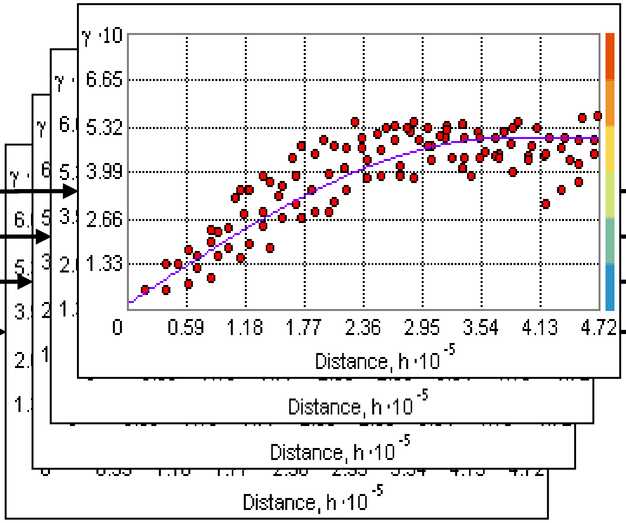
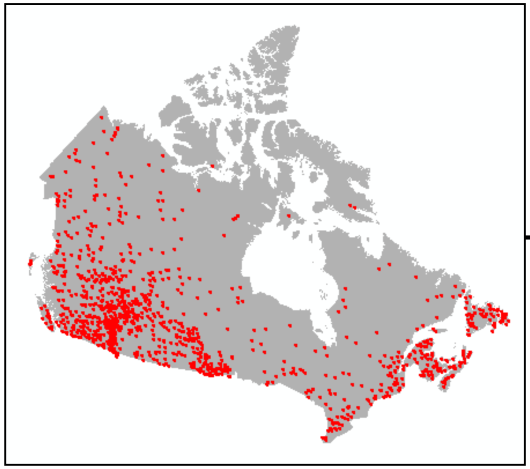
Point	02ZK001	Stlawsb	301	13.2	43.853821	1.651799
Point	02YQ004	Stlawsb	2200	39.7	18.045455	1.279791

Develop monthly semi-variograms

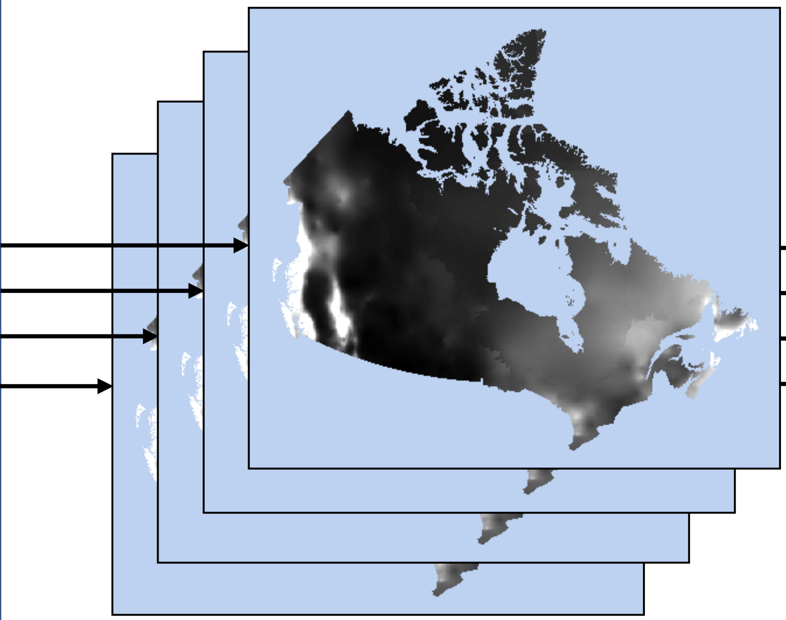


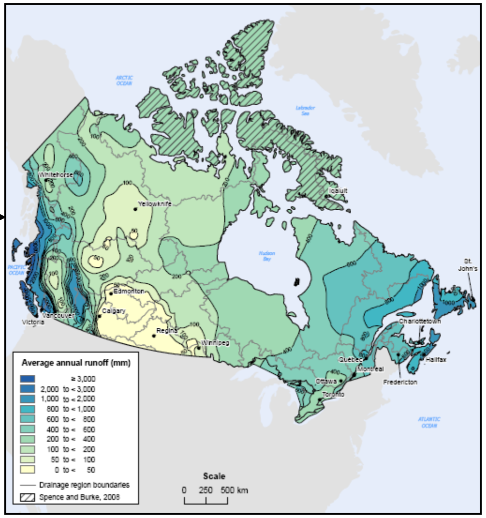
Generate basin centroids



Interpolate monthly surfaces

Summarize to generate outputs





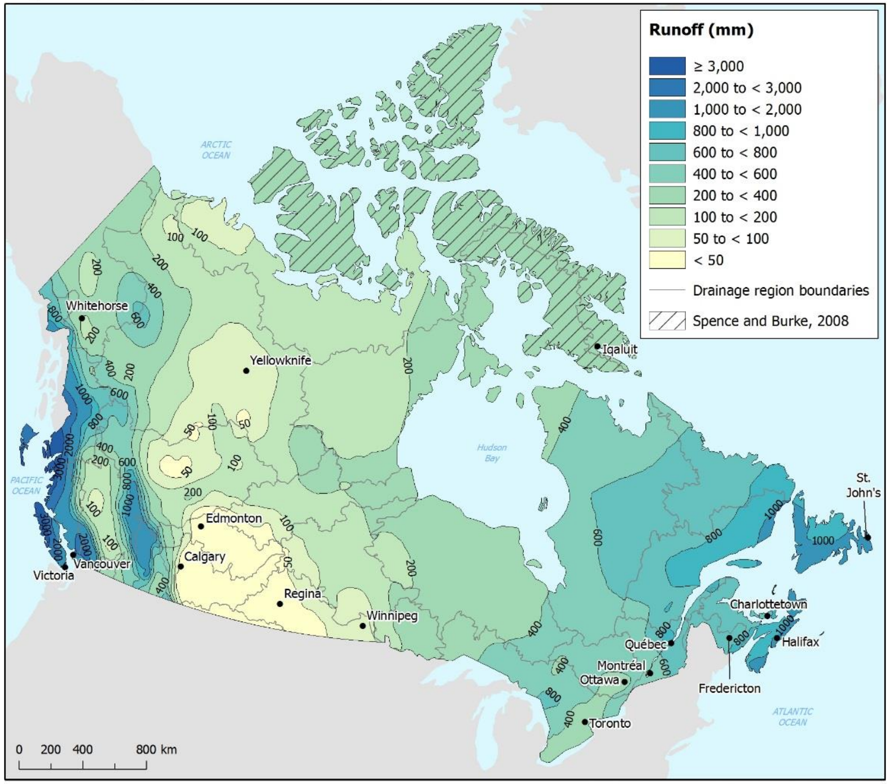
Average annual water yield by drainage region, 1971 to 2004

	Drainage region code	Water yield	
		Volume [1]	Volume per unit area
	number	km^3	m^3 per m^2
Canada		**3,472.3**	**0.348**
Pacific Coastal	1	513.7	1.536
Fraser–Lower Mainland	2	128.6	0.552
Okanagan–Similkameen	3	4.2	0.270
Columbia	4	67.7	0.776
Yukon	5	106.0	0.318
Peace–Athabasca	6	99.9	0.206
Lower Mackenzie	7	246.3	0.185
Arctic Coast–Islands	8	231.3	0.131
Missouri	9	0.5	0.019
North Saskatchewan	10	10.2	0.068
South Saskatchewan	11	9.6	0.054
Assiniboine–Red	12	6.9	0.036
Winnipeg	13	25.4	0.236
Lower Saskatchewan–Nelsc	14	47.6	0.132
Churchill	15	49.4	0.158
Keewatin–Southern Baffin Is	16	192.0	0.204
Northern Ontario	17	199.2	0.288
Northern Quebec	18	516.3	0.549
Great Lakes	19	133.1	0.419
Ottawa	20	62.6	0.428
St. Lawrence	21	71.3	0.600
North Shore–Gaspé	22	292.2	0.792
Saint John–St. Croix	23	29.2	0.697
Maritime Coastal	24	103.6	0.849
Newfoundland–Labrador	25	325.4	0.856

Average annual run-off

- The average annual water yield—an estimate of Canada’s supply of renewable freshwater—was 3,478 km3 from 1971 to 2013.
- This volume is equivalent a depth of 349 mm across the entire country.

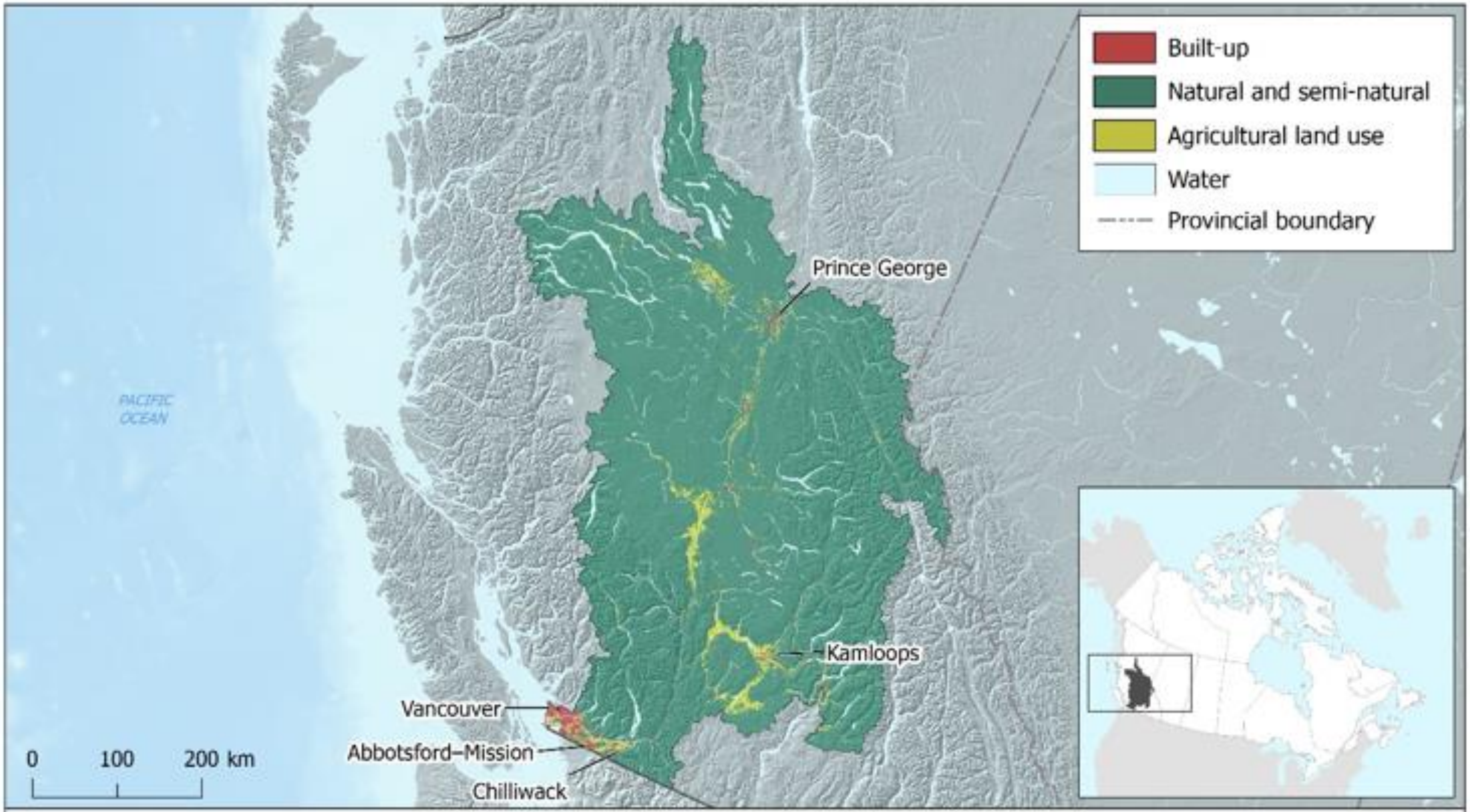
Map 2.1 Average annual runoff in Canada, 1971 to 2013



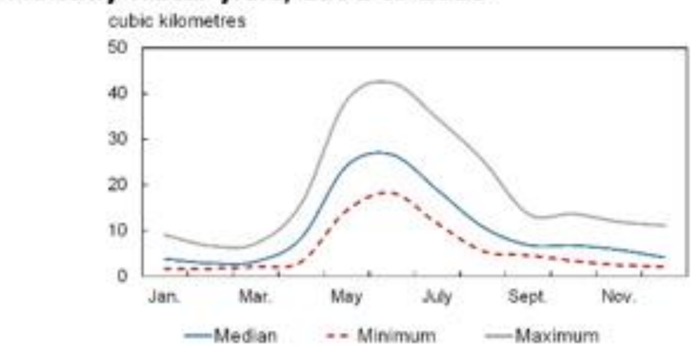
Note: Runoff data were derived from discharge values from hydrometric stations for the period 1971 to 2013, except the Arctic Islands where estimates were taken from Spence and Burke, 2008.

Sources: Statistics Canada, Environment, Energy and Transportation Statistics Division, 2017, special tabulation from Environment and Climate Change Canada, 2015, *Water Survey of Canada, Archived Hydrometric Data (HYDAT)*, www.wsc.ec.gc.ca/hydat/H2O\index_e.cfm?cname=main_e.cfm (December 3, 2015); Spence C., and A. Burke, 2008, “Estimates of Canadian Arctic Archipelago Runoff from Observed Hydrometric Data,” *Journal of Hydrology*, Vol. 362, pp. 247–259.

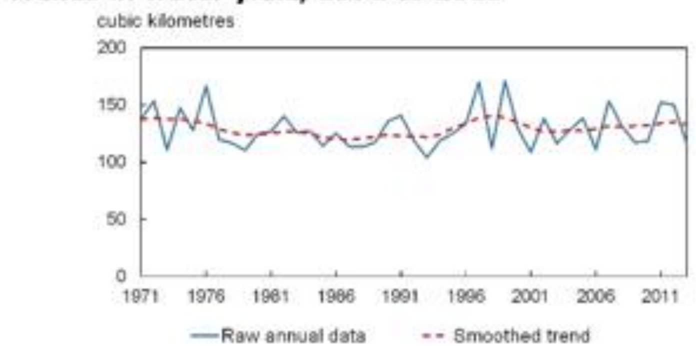
Map 3.3.2
Land use and water yield for the Fraser–Lower Mainland drainage region



Monthly water yield, 1971 to 2013



Trends in water yield, 1971 to 2013



Challenges of using EO for Official Statistics

1. Datasets created from EO are usually not designed for official statistics
2. NSO workflow changes from data creation to data evaluation and integration of the EO datasets (see next slide)
3. NSO needs to adapt in order to:
   A. Develop methodologies to properly interpret datasets to create official statistics
   B. Evaluate global datasets that are often designed without regional considerations
   C. Keep up with ever increasing number of EO generated datasets (continuous risk of falling behind and loosing relevance)
   D. Adjust the national or regional data where local data of better quality highlights important shortcomings of the national or regional EO dataset
   E. Evaluate EO data where other data often do not exist
   F. Influence EO producers to integrate official statistics objectives into the EO processing workflow from the beginning
4. There is now also a call on NSO to create statistical data from raw satellite data (Ref. U.N. Global Working Group on Big Data for Official Statistics)

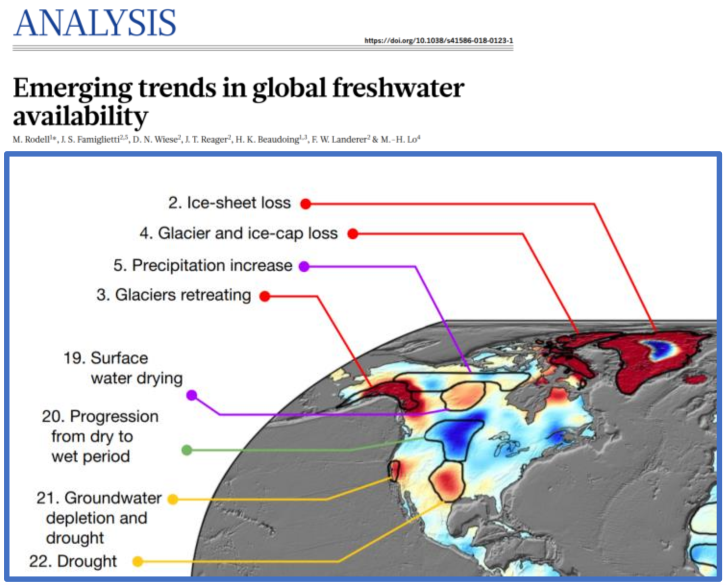
NSO workflow changes from data creation to data evaluation and integration of the EO datasets

Data producer	Data	• Earth observation (satellite and airborne) • Geospatial data layers • Field data
	Preprocessing (data preparation)	• Geographical registration, correction of the effect of elevation (orthorectification) • Corrections and calibrations • Mathematical transformation to enhance images to make them more suitable to meet requirements
	Digital image processing for information extraction	• Use of computer's decision-making capability to identify and extract specific pieces of information • Human operators instruct the computer and evaluate the significance of the extracted information
	Quality control	• Accuracy assessment • Document uncertainties and limitations associated with the approach
Data user	Integration	• Horizontal and vertical integration with other data layers • Document data sources and accuracies
	Results	• Baseline • Change detection/ • Documentation • Etc.

Change in total water storage (TWS) using GRACE satellite data

- Collaborating with science department (Natural Resources Canada) to produce long term trends in total water storage (TWS)
- TWS can be used in an account or for validation of other water accounts data
- TWS is a combination of surface water, ground water and soil moisture

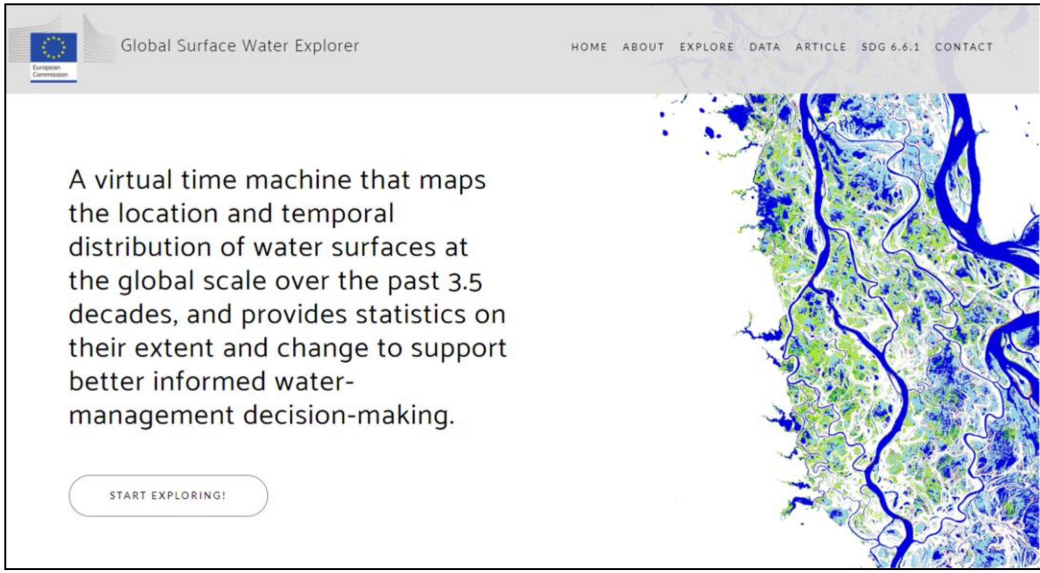
Gravity Recovery and Climate Experiment (GRACE) - NASA



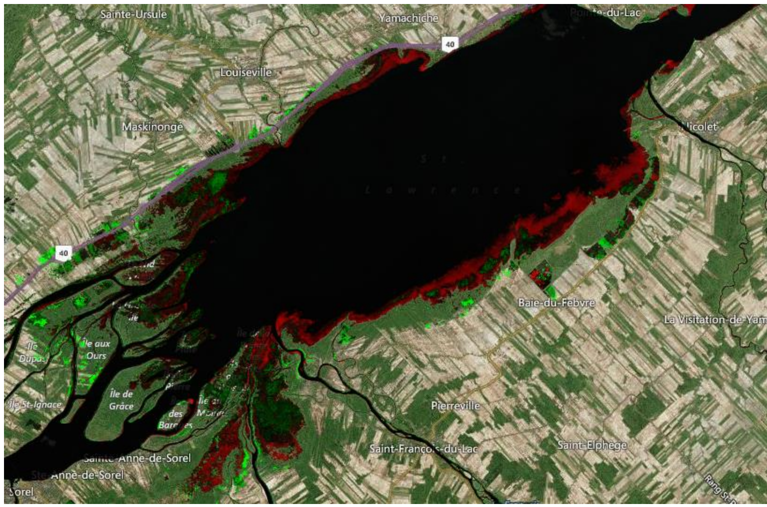
Global Surface Water (GSW)

- Produced by European Commission's Joint Research Centre
- Maps the location and temporal distribution of water surfaces at the global scale over the past three decades and provides statistics on the extent and change of those water surfaces:

1. Water Occurrence (1984-2015)
2. Water Occurrence Change Intensity (1984-1999 to 2000-2015)
3. Water Seasonality (2014-2015)
4. Annual Water Recurrence (1984-2015)
5. Water Transitions (First year to Last Year)



Measuring change in extent



Differences between all homologous pairs of months were averaged to create the surface water occurrence change intensity map

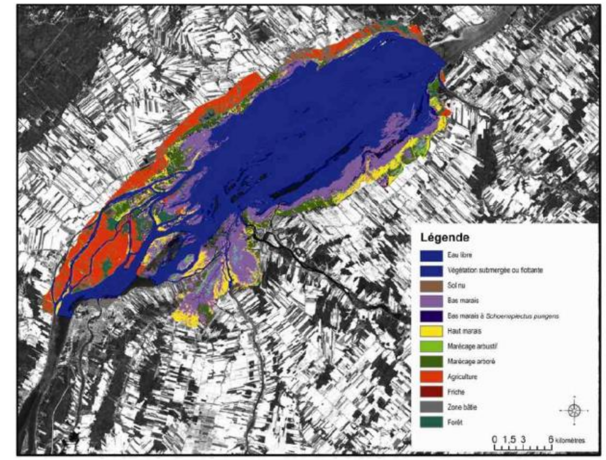
Source: Jean, Martin, et Guy Létourneau. 2011. *Changements dans les milieux humides du fleuve Saint-Laurent de 1970 à 2002*, Environnement Canada, Directi sciences et de la technologie, Monitoring et surveillance de la qualité de l'eau au Québec, Rapport technique numéro 511, 302 pages.

1. The GSW – decrease area was compared to the Wetland maps produced by Environment and Climate Change Canada for the same time periods.

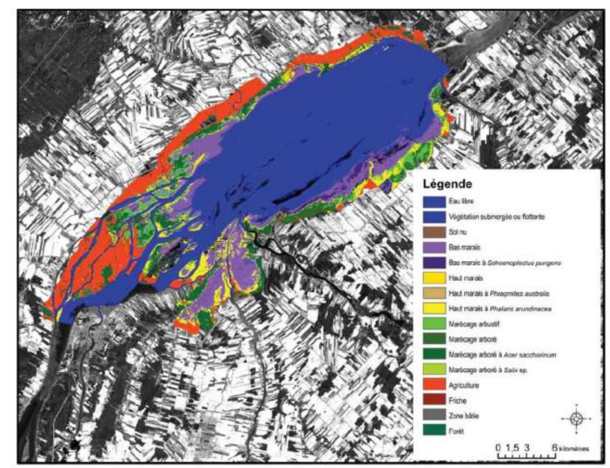
2. The wetland maps show low marshes (purple) where GSW has identified water decrease

3. Marshes are periodically or permanently flooded, there are no or few trees and bushes, and in season vegetation can be seen above water.

Milieux humides du lac Saint-Pierre en 1990-1991



Milieux humides du lac Saint-Pierre en 2000-2002



Conclusion

- Currently, *in-situ* Earth observation is used to compile the Water Asset Account
  - Global run-off databases could be used to estimate renewable water, with caveats

- Satellite Earth observation (SEO) is used to map land cover, providing valuable *contextual* information for the interpretation of the Water Accounts
  - Quantity and quality of water is influenced by land cover and land use

- It is likely that SEO will eventually be used to measure some variables of the Water Accounts
  - Selected parameters for a Water Quality Account
  - To measure change in the total mass of the water assets over time
  - To measure extent and change in extent of water area
    - although not a variable in the accounts, can be used as an indicator

Thank you!