EROSION: INDICATION IN THE WATER LEVEL AND FLOW DYNAMICS

R. VEDOM, HYDROLOGY AND ENVIRONMENT

"EARTH, WIND AND WATER – ELEMENTS OF LIFE", CWRA-CGU NATIONAL CONFERENCE, BANFF, ALBERTA, JUNE 5-8, 2012

OBJECTIVE

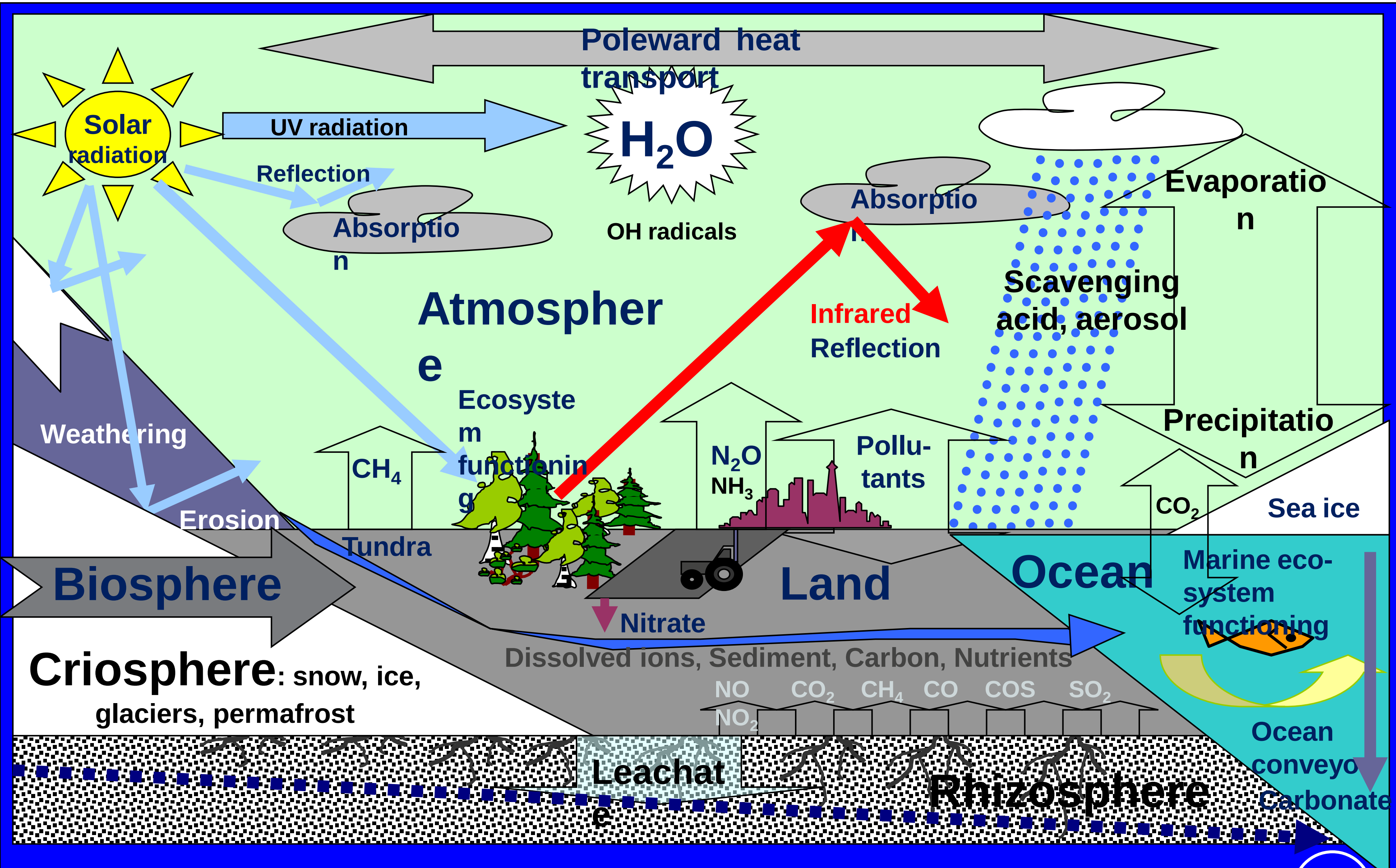
To test the Harmonized Frequencies Analysis (HFA) for erosion assessment

***Erosion definition*: wearing away and transport of the soil by running water, glaciers, wind and waves**

***HFA definition*: the parametrical and statistical analysis of the hydrological cycle integrity and functionality under the Law of Structural Stability or Harmony of Systems**

The Law states: natural systems in process of their self-organization find harmonious structure, stationary regime of their existence, structural and functional stability

HFA: DYNAMIC INTEGRITY AND FUNCTIONALITY OF THE WATER CYCLE



HFA is

the technical solution for the water, matter and energy cycles integrity, functionality, and scale-invariance;

the mathematical combination of asymptotic, uniformly bounded, and structural stabilities of the dynamic water system;

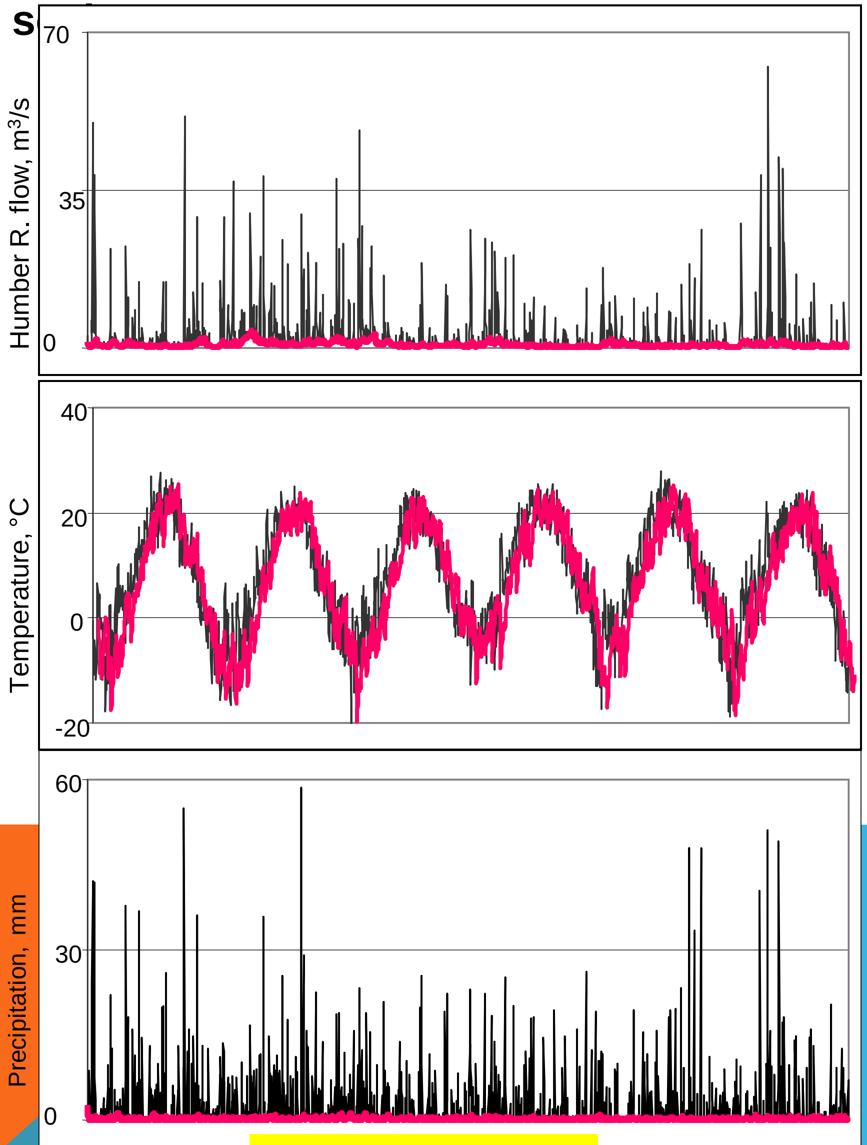
the statistical manifestation of the “componential” independency of the system’s variables within a finite population;

Methodically: the parametrical and statistical analysis of a special way processed and structured data within a single system

Signal processing → harmonization → parametrical and statistical analysis

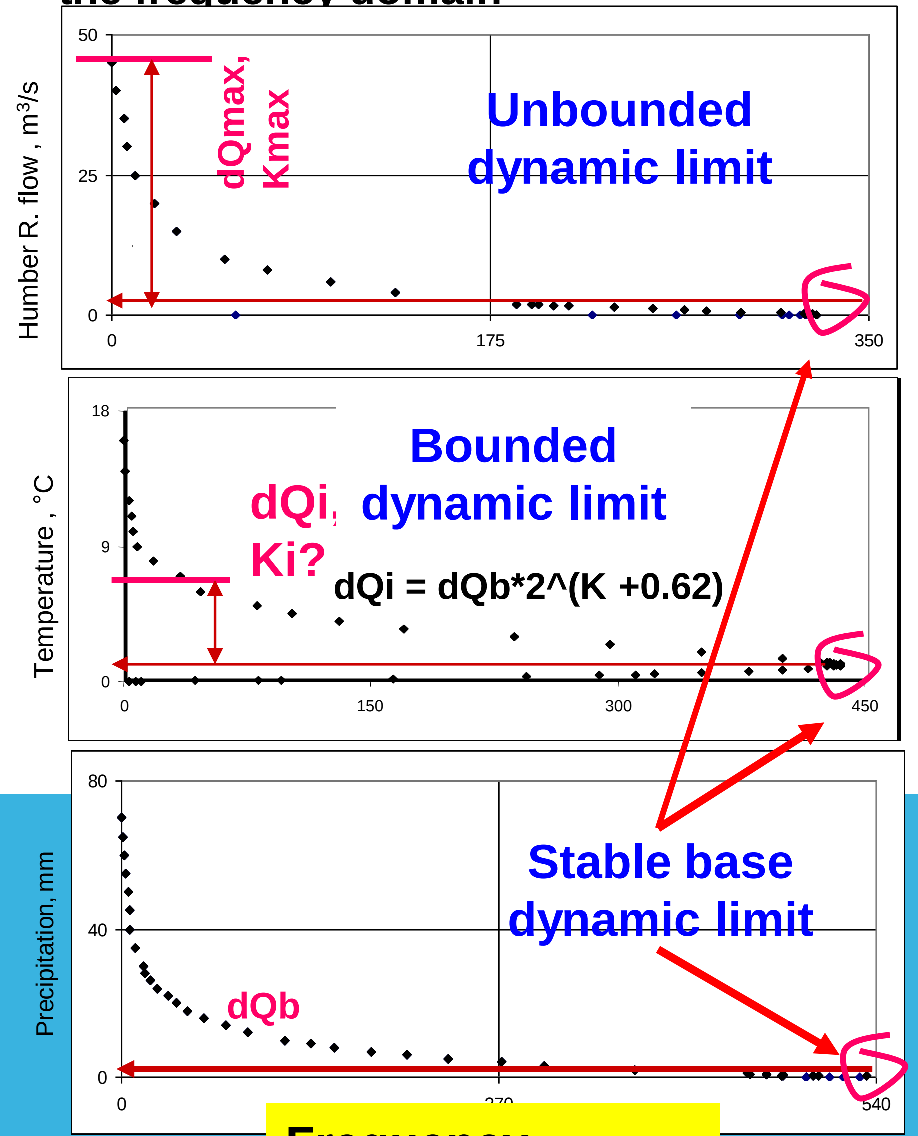
SIGNAL PROCESSING: CUSTOM CONVOLUTION DIGITAL FILTER

Variables in the time domain, daily s



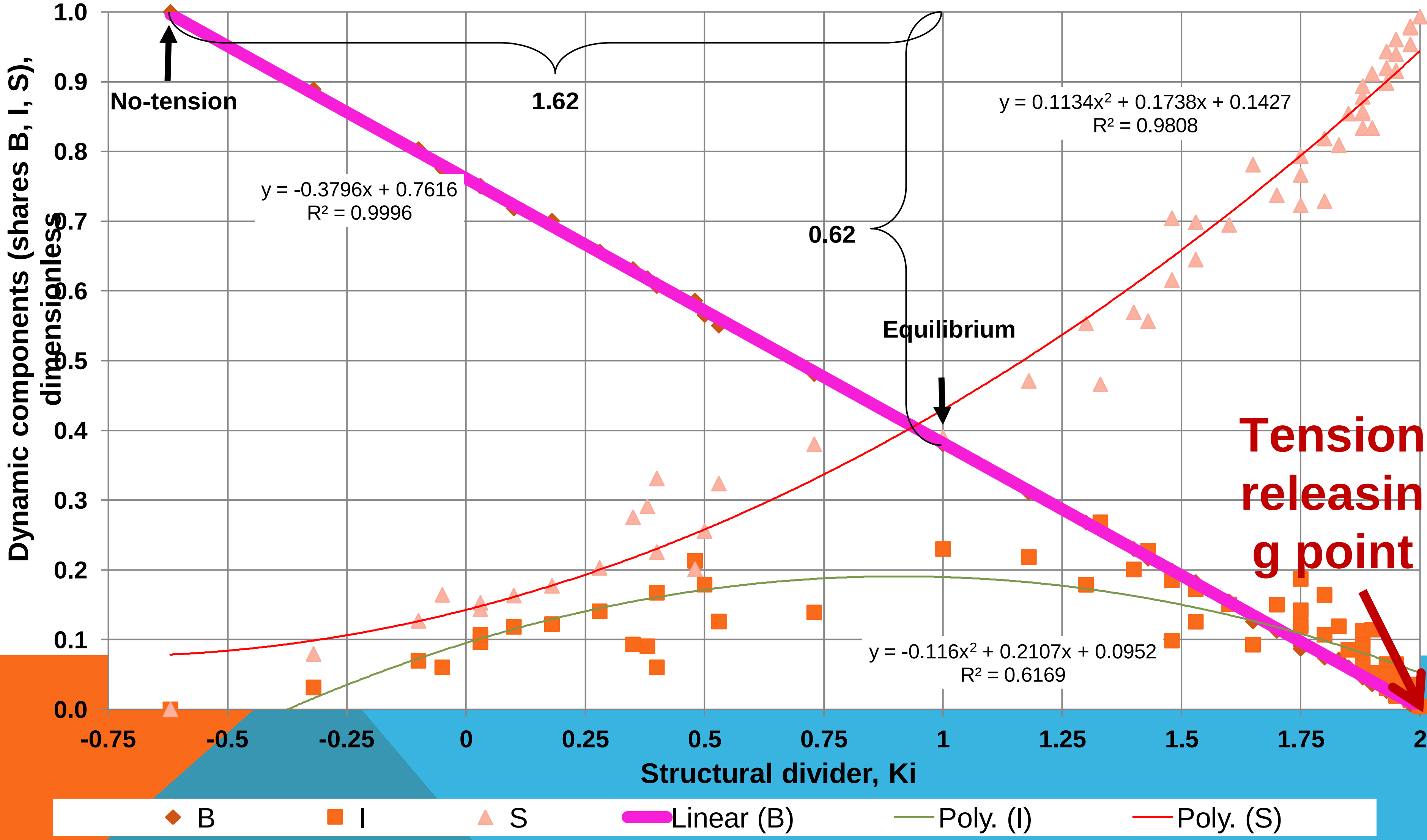
Time domain

Positive daily gradients (dQ) distribution in the frequency domain



Frequency

THE GOLDEN SHC: THE UNIVERSAL SHC



DATA USED

Period: 2004-2009

Station ID	A, km2	Station ID	A, km2
HB001	205	HC019	93.5
HB008	127	HC022	186
HB013	62.2	HC024	316
HB018	402	HC027	58
HB020	32.3	HC028	77.7
HB025	615	HC031	148
HC030	204	HC032	94.8
HC017	63.2	HC049	251
HC033	70.6	HC048	Lake level, m
HC003	800	Hamilton airport	
HC009	197	Toronto Pearson airport	
HC018	106		

UNIVERSAL (GOLDEN) SHC VS PARTICULAR SHCs

Location	K_{trp}	Rb^2	Rs^2	Ri^2
Average meteo	3.4	0.9986	0.9734	0.7072
Hamilton A	2.6	0.9993	0.9773	0.7319
Toronto A	2.1	0.9996	0.9798	0.7256
GOLDEN	2	0.9998	0.9813	0.6905

PARAMETRICAL RESULTS

2004-2009	F, kn	dQb	Nb	PBD	PID	PSD	Total
HC048 lake level		0.010	410	-0.1	-0.1	0.0	-0.2
HB001 flow	205	0.317	220	74.6	226.9	14.6	316.1
HB001 level		0.006	254	0.7	1.9	0.2	2.8
HB008 flow	127	0.291	206	63.6	235.2	1.3	300.0
HB008 level		0.004	235	0.3	0.8	0.1	1.2
HB013 flow	62.2	0.209	254	80.1	311.6	13.7	405.4
HB013 level		0.002	289	0.7	2.3	0.6	3.6
HB018 flow	402	0.249	206	65.6	241.3	7.3	314.2
HB018 level		0.009	239	1.2	3.7	0.3	5.2
HB020 flow	32.3	0.341	233	99.9	369.9	41.7	511.6
HB020 level		0.011	286	1.5	3.8	0.2	5.6
HB025 flow	615	0.244	187	56.5	232.0	127.1	415.6
HB025 level		0.005	230	0.9	3.0	0.5	4.3
HC030 flow	204	0.637	266	345.5	1695.9	90.6	2132.0
HC030 level		0.014	278	2.2	6.9	0.3	9.4
HC017 flow	63.2	0.301	247	162.7	777.6	39.7	980.0
HC017 level		0.008	270	1.9	6.6	0.7	9.3
HC033 flow	70.6	0.708	289	432.5	2088.4	36.1	2557.0
HC033 level		0.007	311	2.1	7.6	0.5	10.2
HC003 flow	800	0.500	206	135.9	514.7	103.7	754.3
HC003 level		0.019	218	1.3	2.9	0.3	4.4
HC009 flow	197	0.350	202	94.7	331.9	22.3	449.0
HC009 level		0.009	217	1.1	3.0	0.4	4.5
HC018 flow	106	0.651	213	210.4	820.8	27.1	1058.3
HC018 level		0.005	247	1.6	6.2	1.9	9.7
HC019 flow	93.5	0.481	194	147.6	565.1	16.0	728.7
HC019 level		0.008	219	0.8	2.4	0.6	3.8
HC022 flow	186	1.720	215	307.9	815.5	22.8	1146.2
HC022 level		0.008	230	1.7	6.8	0.6	9.1
HC024 flow	316	0.949	265	349.2	1458.1	142.4	1949.8
HC024 level		0.011	270	2.2	8.4	0.6	11.2
HC027 flow	58	1.224	287	606.6	2564.3	21.0	3191.9
HC027 level		0.016	314	3.4	10.9	0.5	**14.8**
HC028 flow	77.7	0.399	190	142.7	710.4	37.2	890.4
HC028 level		0.010	219	1.8	5.5	0.7	8.0
HC031 flow	148	0.209	212	99.5	458.6	82.7	640.8
HC031 level		0.008	236	1.9	6.7	2.1	10.7
HC032 flow	94.8	0.306	172	69.2	258.1	15.0	342.3
HC032 level		0.008	200	1.2	3.3	0.9	5.4
HC049 flow	251	0.438	214	144.8	573.8	54.2	772.8
HC049 level		0.012	228	2.1	6.1	0.8	8.9
maximum		1.720	289	606.6	2564.3	142.4	3191.9
minimum		0.019	314	3.4	10.9	2.1	14.8
criteria of instability							
flow				max	max		max
level				max	max		>= 2.5*n

$PBD_i = dQb_i*Nb_i*HEI_i$

$PID_i = dQi_i*Ni_i*HEI_i$

$PSD_i = dQs_i*Ns_i*HEI_i$

PBD_i, PID_i, PSD_i – power of base, inter and storm dynamics of each variable

dQb_i, dQi_i, dQs_i – base, inter and storm dynamic limits (positive gradients) and the corresponding frequencies of their occurrence (N)

$HEI_i = (S_i-I_i)(K_i-K_t)/(B_t-I_t)$

HEI_i – hydrosphere elasticity index of each variable

B_i, I_i, S_i – base, inter and storm shares of each variable

B_t, I_t – base and inter shares of temperature

K_i, K_t – structural dividers of each variable and temperature

Criteria of instability for a several years period:
PBD and PID for level and flow are the highest among all locations; the sum of the power dynamics for level (roughly) ΣPD >=2.5*n, where **n** is number of years in period

CROSS-CORRELATION RESULTS OF EACH STATION'S LEVEL WITH METEOROLOGICAL VARIABLES AND LAKE ONTARIO LEVEL

	2005		GP	Rb^2 =	0.9996		Rs^2 =	0.9799		Ri^2 =	0.5420
Between components				Totals				Within components			
Ranged average		Ranged ABS average		Ranged average		Ranged ABS average		Ranged averages		Ranged ABS average	
0.15	Prec_B	0.25	Temp_B	0.20	L27	0.36	Humid	0.27	L27_S	0.39	Temp_B
0.15	Prec_I	0.23	Prec_I	0.18	Prec	0.33	Prec	0.26	Prec_S	0.33	Humid_B
0.14	L_027_S	0.22	Prec_B	0.12	Humid	0.32	Wind	0.21	Humid_S	0.31	L27_S
0.11	Prec_S	0.22	L_027_S	0.11	Wind	0.32	L27	0.19	Lake_S	0.31	Prec_S
0.11	L_027_I	0.21	Humid_B	0.11	Lake	0.31	Temp	0.19	WinDir_S	0.29	Snow_B
0.11	L_027_B	0.21	Prec_S	0.09	WinDir	0.30	Pressure	0.18	L27_I	0.28	Prec_B
0.10	WinDir_S	0.20	Pressure_B	0.06	Snow	0.26	Lake	0.18	Prec_I	0.27	Lake_B
0.10	Temp_S	0.19	Snow_B	-0.02	Temp	0.25	Snow	0.18	Wind_S	0.26	Humid_S
0.10	Snow_S	0.19	Humid_S	-0.07	Pressure	0.22	WinDir	0.17	Snow_S	0.26	Prec_I

CROSS-CORRELATION OF ALL HYDROMETRIC STATIONS WITH DIFFERENT METEOROLOGICAL VARIABLES IN WARM AND COLD PERIODS

	Lake Ontario		Precipitatio										re	
Warm period of 2004 (March 23 - Septe														
Components	0.50	**hc031_I**	0.51	**hc031_**										**031_I**
	0.50	**hc017_I**	0.51	**hc017_**										**020_B**
	0.50	**hb008_I**	0.51	**hb008_**										**030_B**
Totals	0.78	**hc031**	0.81	**hc031**										**031**
	0.78	**hc003**	0.81	**hc003**										**003**
	0.77	**hc017**	0.81	**hc017**										**017**
Within	0.85	**hc022_B**	0.89	**hc022_**										**031_B**
components	0.85	**hc031_B**	0.89	**hc031_**										**022_B**
	0.64	**hc003_B**	0.63	**hc003_**										**003_B**
Cold period of 2004-2005 (September 2														
Components	0.48	**hc031_S**	0.49	**hc031_**										**031_S**
	0.47	**hc017_S**	0.48	**hc017_**										**017_S**
	0.47	**hb008_S**	0.47	**hb008_**										**025_S**
Totals	0.78	**hc022**	0.79	**hc022**										**022**
	0.77	**hc031**	0.78	**hc031**										**031**
	0.77	**hc017**	0.78	**hc017**										**018**
Within	0.79	**hc022_S**	0.80	**hc022_**										**022_S**
components	0.79	**hc017_S**	0.80	**hc017_S**	0.79	**hc017_S**	0.79	**hc017_S**	0.79	**hc018_S**	0.79	**hc017_S**	0.78	**hc017_S**
	0.78	**hc018_S**	0.79	**hc018_S**	0.79	**hc018_S**	0.78	**hc018_S**	0.79	**hc017_S**	0.79	**hc018_S**	0.78	**hc018_S**
Warm period of 2005 (March 23 - September 23)														
Components	0.56	**hc003_B**	0.56	**hc022_I**	0.54	**hc022_I**	0.55	**hc022_I**	0.55	**hc022_I**	0.56	**hc022_I**	0.55	**hc030_B**
	0.55	**hc030_B**	0.55	**hc030_B**	0.54	**hc009_I**	0.55	**hc030_B**	0.55	**hc030_B**	0.55	**hc030_B**	0.55	**hc003_B**
	0.55	**hc027_B**	0.55	**hc027_B**	0.54	**hc030_B**	0.55	**hc009_I**	0.54	**hc009_I**	0.55	**hc009_I**	0.55	**hc022_I**
Totals	0.83	**hc003**	0.84	**hc003**	0.79	**hc003**	0.84	**hc003**	0.83	**hc003**	0.84	**hc003**	0.81	**hc003**
	0.81	**hc009**	0.83	**hc022**	0.78	**hc022**	0.82	**hc022**	0.81	**hc022**	0.83	**hc022**	0.79	**hc009**
	0.81	**hc022**	0.82	**hc009**	0.77	**hc009**	0.81	**hc031**	0.80	**hc009**	0.82	**hc009**	0.79	**hc022**
Within	0.89	**hc049_B**	0.88	**hc049_B**	0.83	**hc049_B**	0.86	**hc049_B**	0.85	**hc049_B**	0.89	**hc049_B**	0.85	**hc049_B**
components	0.88	**hc018_B**	0.87	**hc018_B**	0.82	**hc031_B**	0.86	**hc031_B**	0.85	**hc031_B**	0.88	**hc031_B**	0.85	**hc031_B**
	0.87	**hc009_B**	0.87	**hc031_B**	0.82	**hc022_B**	0.86	**hc022_B**	0.85	**hc022_B**	0.88	**hc022_B**	0.85	**hc009_B**

Criteria of instability:
the base component of both the level and discharge has the highest average cross-correlation coefficient with precipitation

CONCLUSIONS

- **HFA is sensitive to identify the drainage area with the highest expectancy of the bank slide type of erosion based on discharge and level dynamics;**
- **The universal Golden SHC can be used for analysis;**
- **The multiple simultaneous criteria of instability are :**
  - ***The parametrical criteria are:* the highest values of PBD and PID for both variables simultaneously, and the highest sum of all powers: PBD+PID+PSD for discharge and for the level it should be = or > 2.5*n;**
  - ***The statistical criteria are:* the highest average cross-correlation coefficient of both discharge and level with meteorological variables among the totals; and the highest average cross-correlation coefficient of base components for both the level and discharge with precipitation**