Elasticity of hydrosphere and its contribution to the sustainable management of water resources

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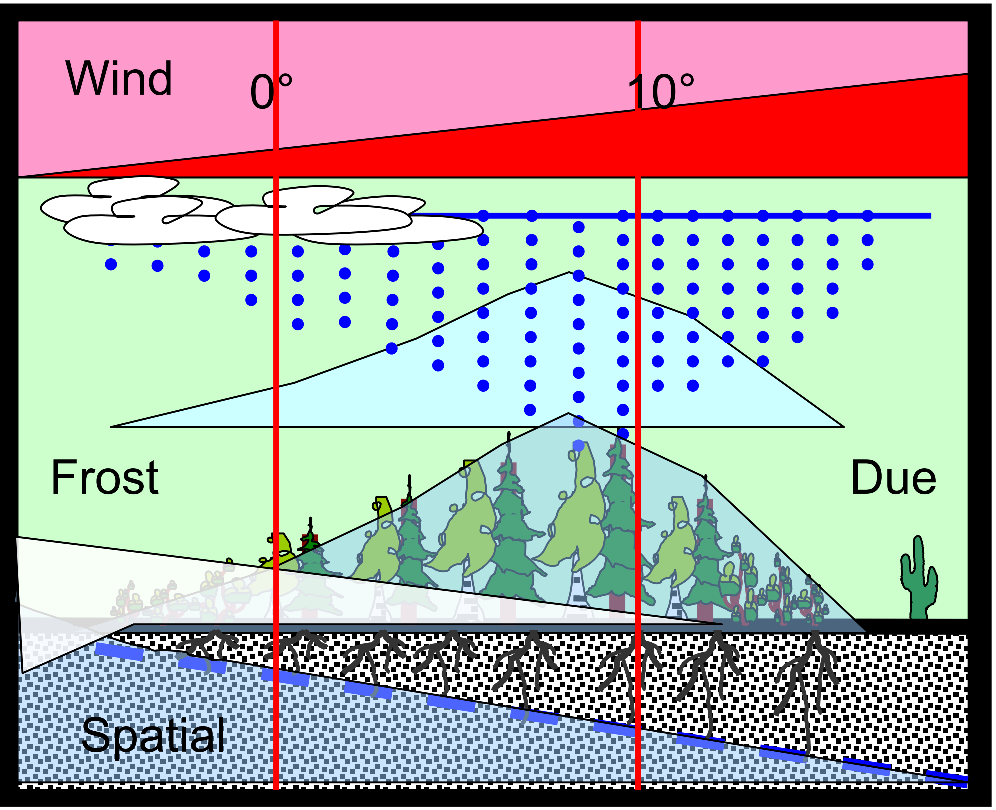
Presentation outline

- Elasticity of hydrosphere: illustration and interpretation in terms of climate and water resources variations
- Tools for assessment: the SimpleBase Delineation Model and the Separated Flux Analysis (SFA)
- Used databases and the idea supporting results: “operation charts” of hydrosphere
- Use for sustainable Water Management

Elasticity of hydrosphere



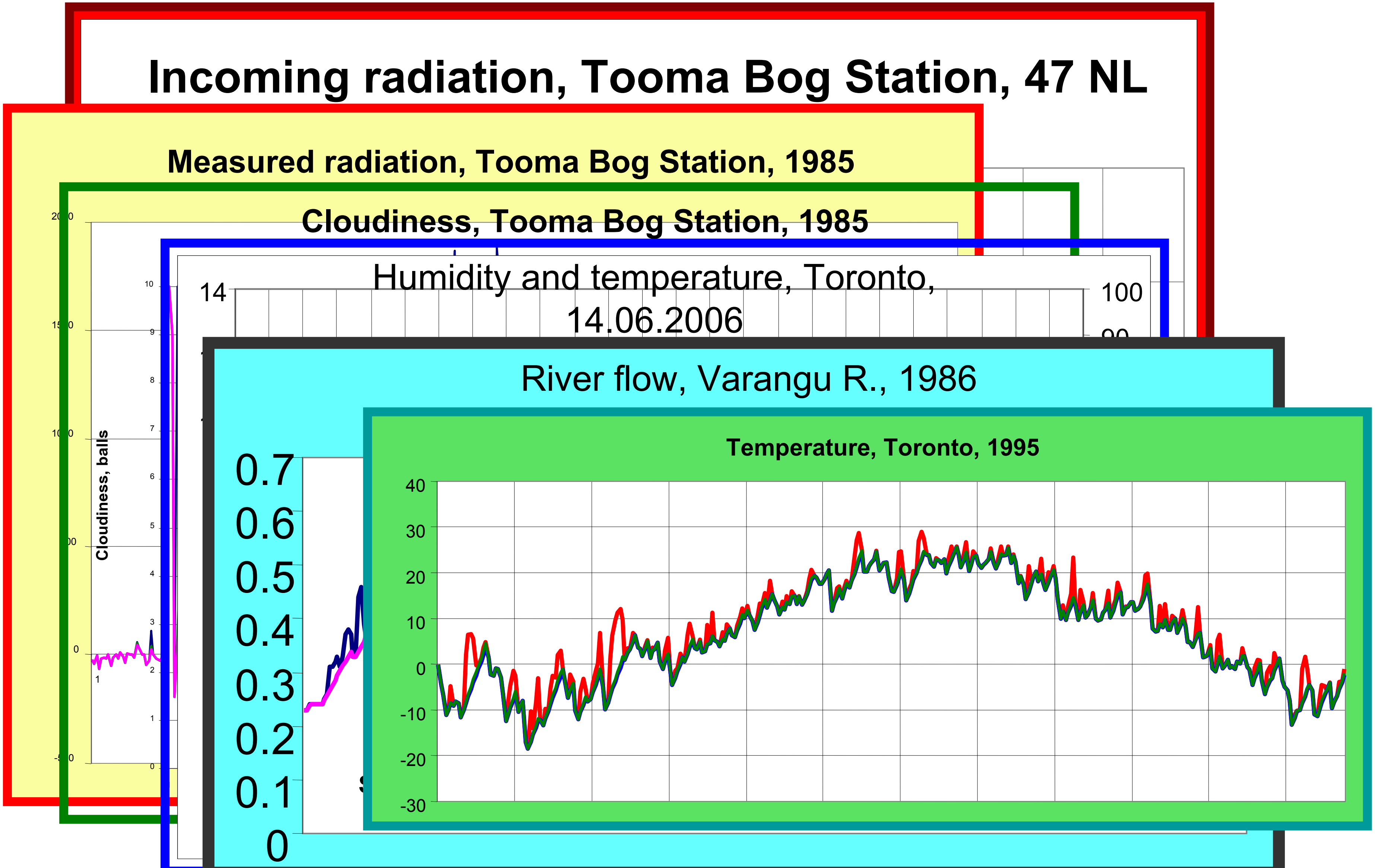
Why elasticity? Why not viscosity or density?

Elasticity is about limits. We need to know limits of water consumption and use.

We need to know natural limits of all structural elements fluctuation in entire hydrosphere

- Elasticity of hydrosphere is an ability or function of hydrosphere to control life-sustaining local and global thermoregimes maintaining certain long-term composition of water phases within it.

Iterative nature of weather parameter fluctuations comes from their diversity and Earth rotation



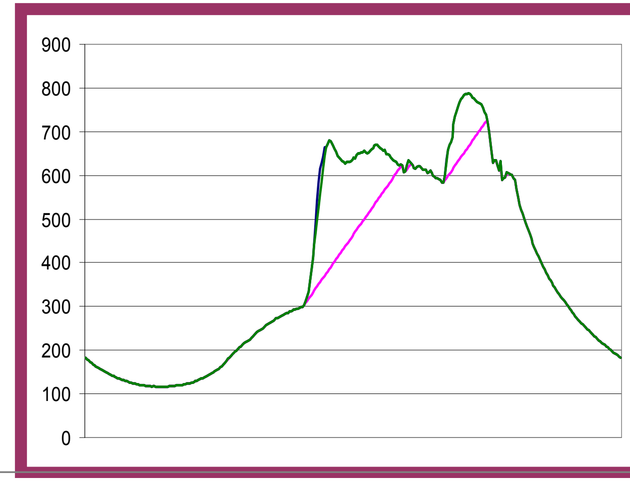
The SimpleBase Delineation Model™

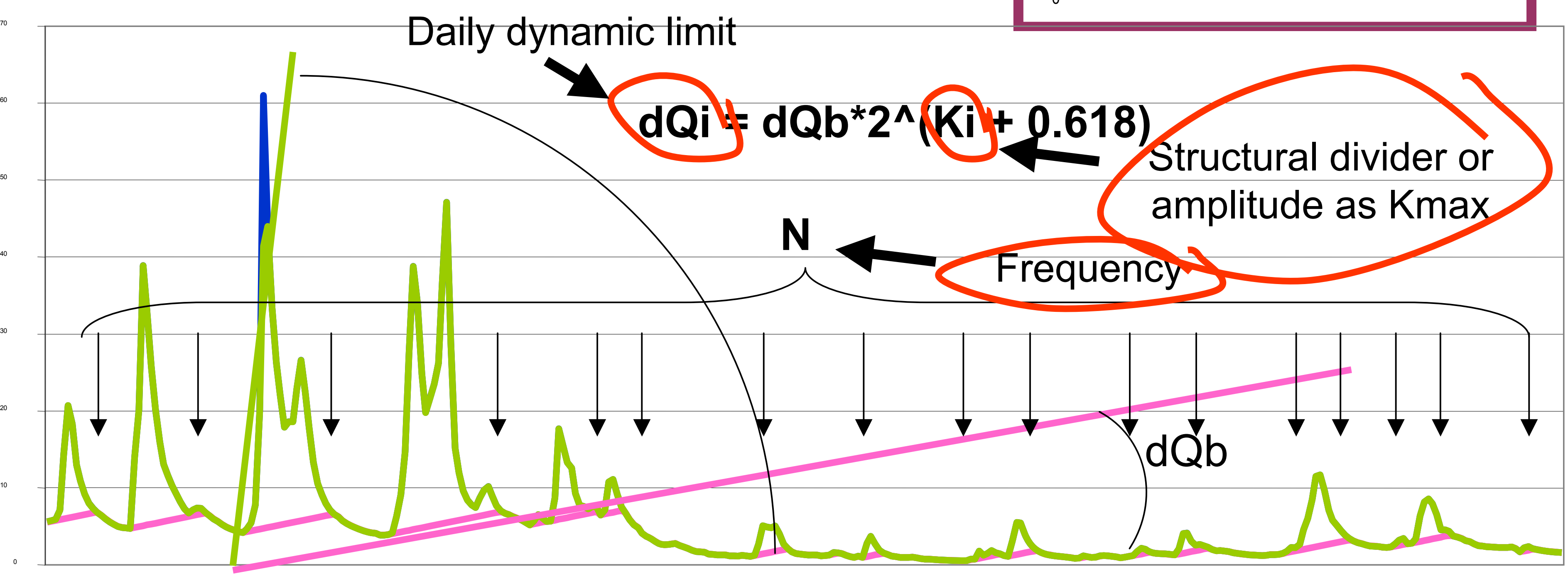
Base component delineation algorithm:

if $(Qt)_t - (Qt)_{t-1} > dQb$,

$\mathbf{(Qb)_t = (Qt)_{t-1} + dQb}$, otherwise $\mathbf{(Qb)_t = (Qt)_t}$,

The key point for delineation is the mathematical definition of a flux, which is the increase of the component followed by its decrease or unchanged condition



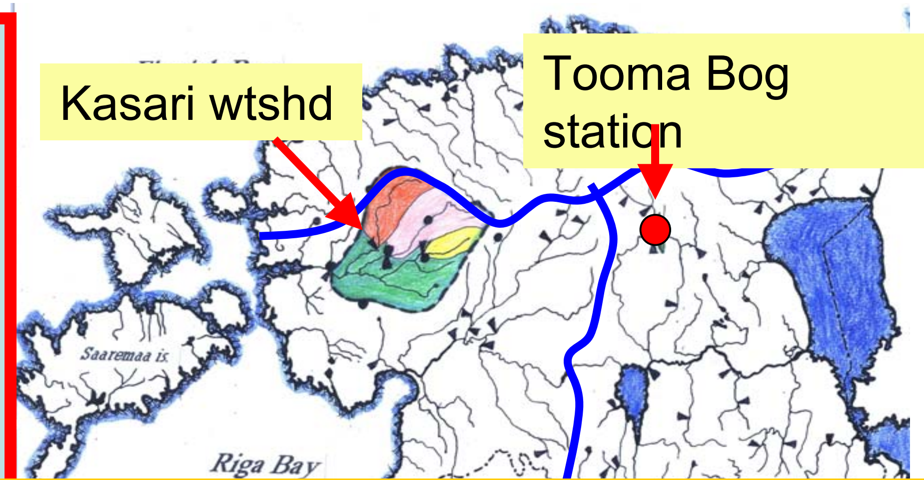


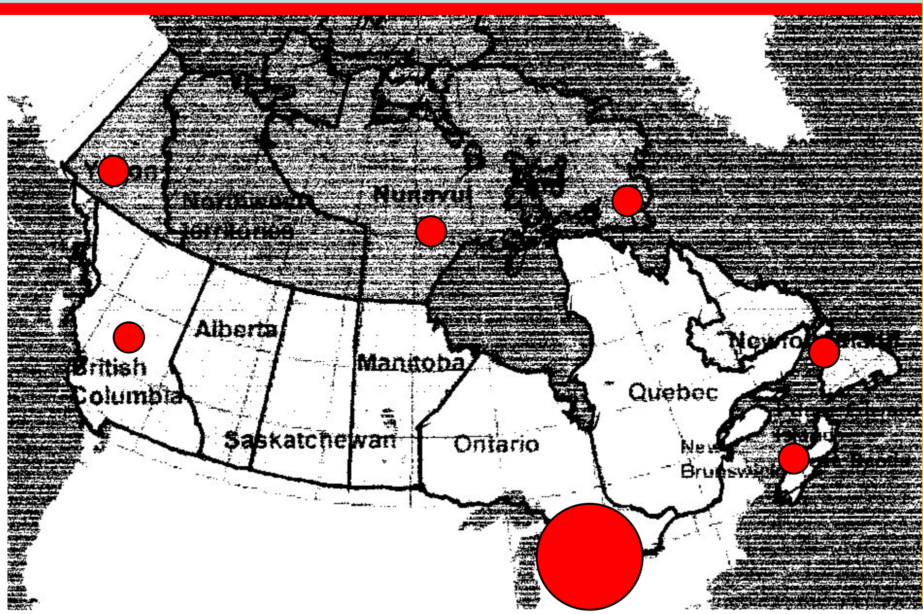
Databases used

Hydrometeorological Survey of Estonia:

Kasary wtshd: **4 subwatersheds**, **1 temperature**, **6 precipitation** stations

Tooma Bog station: complex water and radiation balance station providing standard hydrometeorological, hydrogeological and hydrophysical daily data





Environment Canada: **60 watersheds** and **40 climate stations** from 6 Canadian provinces and territories **(British Columbia, Yukon, Nunavut, Ontario, Nova Scotia and Newfoundland)** for the 1995-2000 periods;

38 natural stream stations of S. Ontario

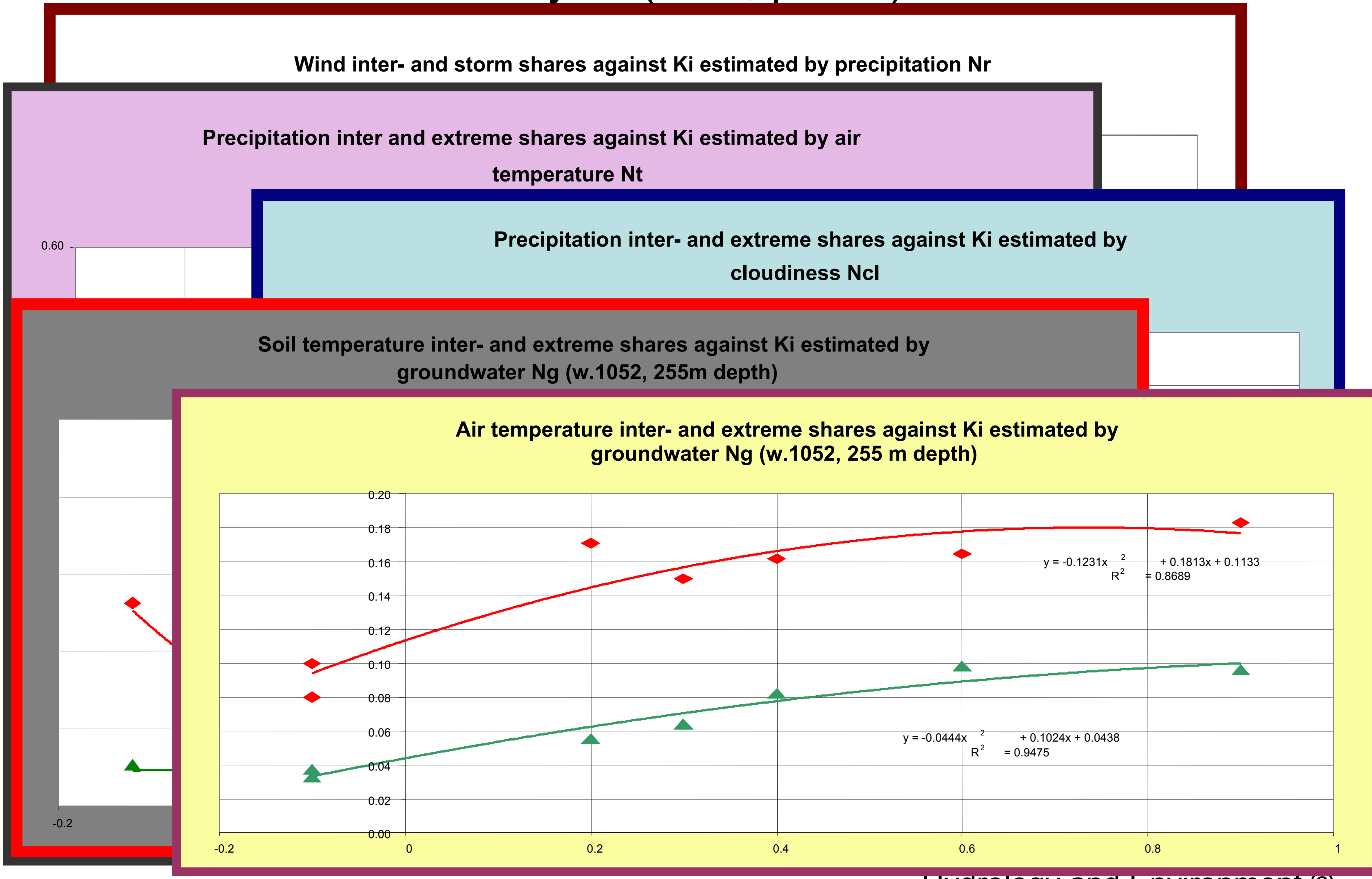
4 stations of hourly data for 1953, 2006 and 1995-2000

Fletcher's Creek daily data of the surface and groundwater quality: March – July 2005

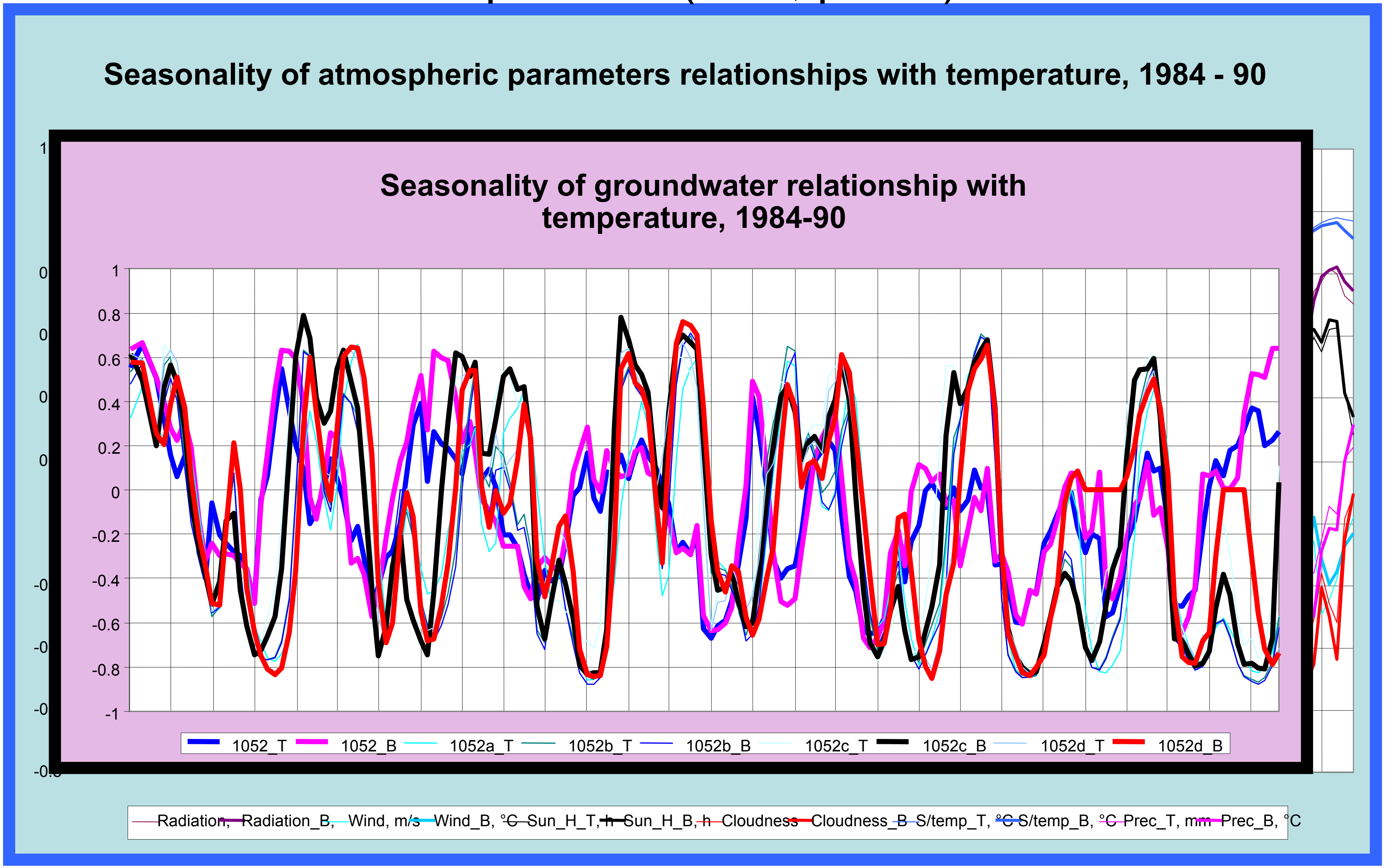
Daily dynamic limits and frequencies of hydro-meteo parameters in ascending order, Tooma Bog Station (Estonia), 1984-90

Parameter/Object	Daily limit	Frequency	Sensor location	Parameter/Object	Daily limit	Frequency	Sensor location
Linnusaare Cr., L/s	1.95	**12**	**Lake-ridge, pine-hollow mire surface**	**226 (pool), cm**	0.84	**30**	surface
Snow (Pine-hollow lndscp), cm	0.99	**12**	surface	**1052b, cm**	0.90	**33**	26 m depth, Tooma 4 wtshd
Snow (Pine-shroub lndscp), cm	0.99	**13**	surface	**214 (pool), cm**	0.91	**33**	Surface, Linnussaare wtshd
Snow (Forest ldscp)	0.99	**13**	surface	**323, cm**	0.96	**33**	2 m depth, Tooma 4 wtshd
Snow (Lake-ridge lndsc), cm	0.99	**13**	surface	**1052, cm**	0.94	**39**	**255 m depth** at Tooma 4 wtshd
Tooma 6 Ch., L/s	0.036	**15**	Mineral surface	**1052a, cm**	0.94	**39**	**145 m depth** at Tooma 4 wtshd
Snow (Mineral soil)	0.99	**15**	surface	**Air Temperature**	0.99	**55**	2 m above surface (mineral soil)
Koluvere Cr., L/s	0.815	**17**	All variaty of landscapes	**Water Pressure, mm**	0.49	**62**	2 m above surface (mineral soil)
Tooma 5 Ch., L/s	0.149	**19**	Pine-hollow, pine-shrub, lake-ridge landscapes	**Soil Temperature, °C**	0.94	**63**	surface (mineral soil)
Tooma 4 Ch. L/s	0.064	**20**	Pine-hollow landscape	**Radiation, cal/m2**	43	**64**	2 m above surface
1052d, cm	0.98	**20**	2 m depth at Tooma 4 wtshd	**Cloud, balls**	0.99	**71**	surface
218, cm	0.97	**24**	2 m depth, Tooma 5 wtshd	**Precipitation, mm**	0.49	**73**	0-2 m above surface
225, cm	0.96	**28**	2 m depth,	**Sun shine, hour**	1.29	**73**	surface (mineral soil)
1052c, cm	0.87	**29**	8 m depth at Tooma 4 wtshd	**Wind, m/s**	0.47	**78**	15 m above surface

Inter/storm component separation: the Separated Flux Analysis (SFA, part 2)



Semi-annual (March – October, November- February) correlation of meteo-elements and groundwater levels with temperature (SFA, part 3)



Defining of top priority parameters for catchments: SFA, part 4

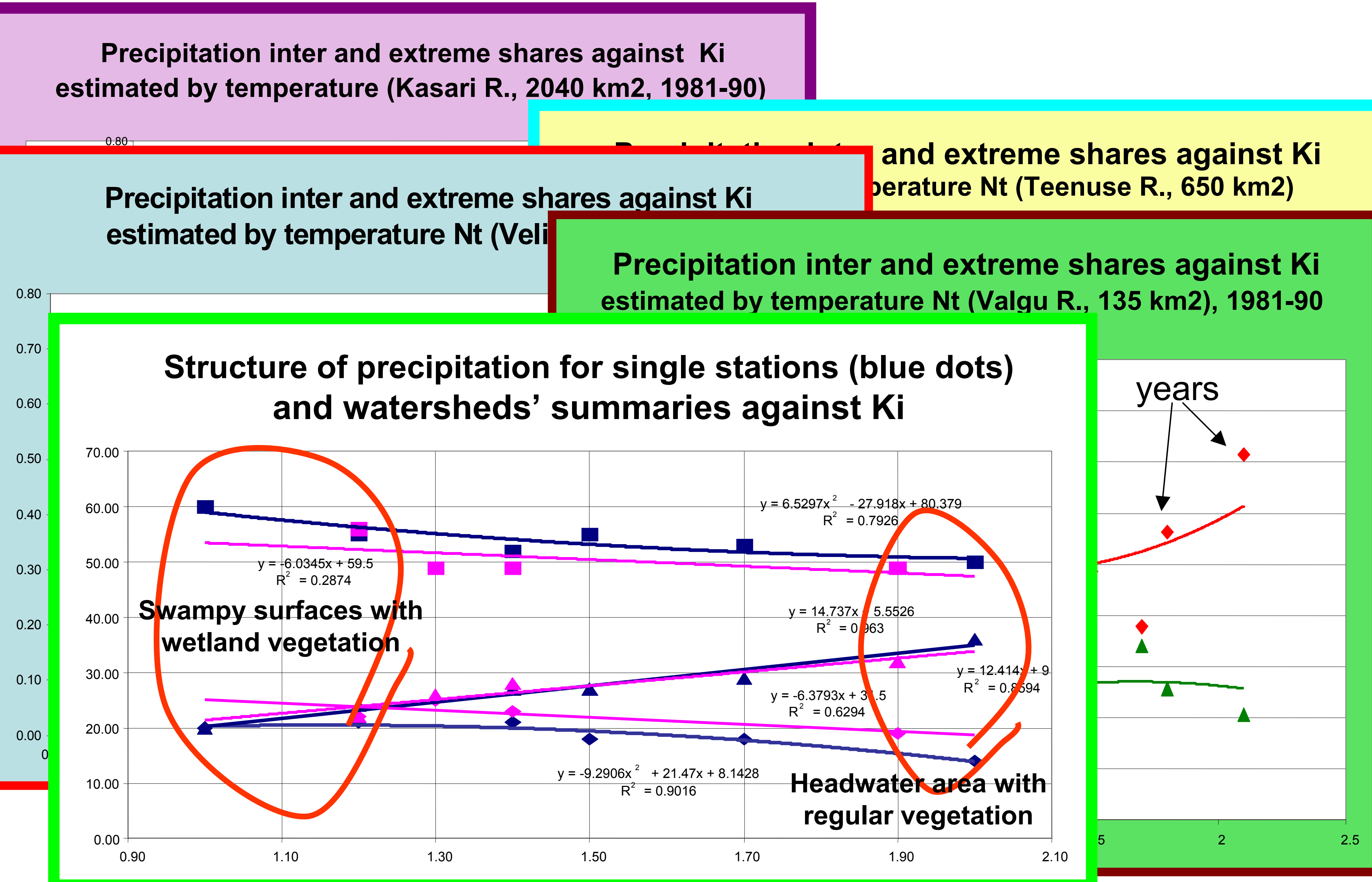
Linnussaare catchment (peat pillow), 1.8 km2

Average corre lation coef.	Parameter	Absolute average coef.	Parameter
0.28	Lin_I	0.54	1052b_B
0.28	Lin_T	0.54	1052b_I
0.28	1052c_I	0.54	1052b_T
0.27	1052c_T	0.54	226_B
0.27	Lin_B	0.53	214_B
0.27	1052c_B	0.53	226_I
0.27	226_T	0.53	226_T
0.27	226_I	0.53	214_I
0.27	226_B	0.53	214_T
0.27	1052b_T	0.51	225_B
0.27	1052b_I	0.51	225_I
0.27	1052a_T	0.51	225_T
0.27	1052a_I	0.49	1052c_B
0.26	1052b_B	0.49	1052a_I
0.26	225_B	0.49	1052a_T
0.26	225_I	0.48	1052a_B
0.26	225_T	0.48	1052c_I
0.26	1052a_B	0.47	e_B, mm
0.24	214_T	0.46	1052c_T
0.24	214_I	0.46	Temp_I, °C

Tooma 6 catchment (mineral soil), 0.035 km2

Average corre lation coef.	Parameter	Absolute average coef.	Parameter
0.12	Snow_T, cm	0.49	S/temp_B, °C
0.12	Snow_I, cm	0.49	S/temp_I, °C
0.12	1052a_T	0.49	Temp_B, °C
0.12	Snow_B, cm	0.49	S/temp_T, °C
0.12	1052a_I	0.48	Temp_I, °C
0.11	1052b_T	0.48	Temper_T
0.11	1052b_I	0.47	e_B, mm
0.11	1052a_B	0.47	e_I, mm
0.11	1052b_B	0.46	e, mm
0.11	1052c_B	0.43	Snow_I, cm
0.10	1052c_I	0.43	Snow_T, cm
0.10	1052c_T	0.43	Snow_B, cm
0.10	T6_I	0.42	Radiation_I, °C
0.10	Wind_I, °C	0.42	Radiation,
0.10	Wind, m/s	0.42	Radiation_B,
0.09	T6_T	0.37	1052b_B
0.09	Wind_B, °C	0.37	1052b_I
0.09	T6_B	0.37	1052b_T
0.09	1052d_T	0.35	Sun_H_I, h
0.09	1052d_I	0.35	Sun_H_B, h

Precipitation structure change against watershed area and station location: Kasari R. watershed and subwatersheds (1981-90)



Precipitation structure for some areas of Canada, 1995-2000

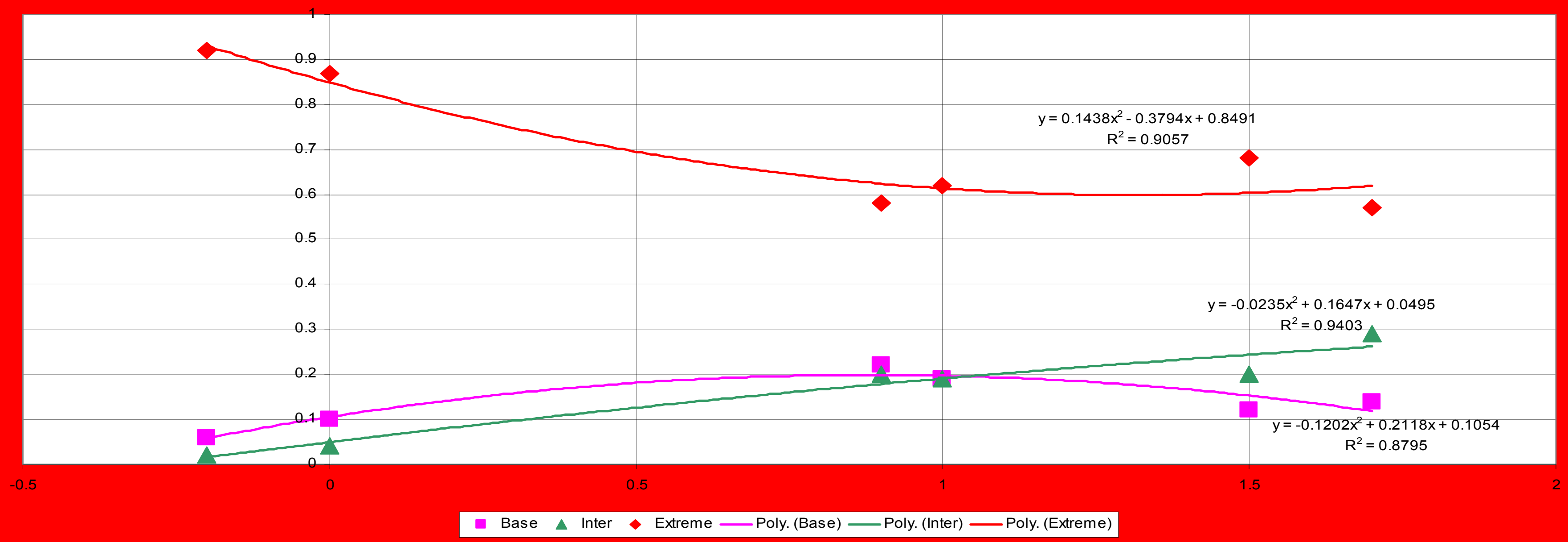
L.Williston wtshd, BC

Newfoundland

Kazan R. - Thelon R. wtshd, Nunavut

Alsek R. wtshd, Yukon

Region 615, S.Ontario



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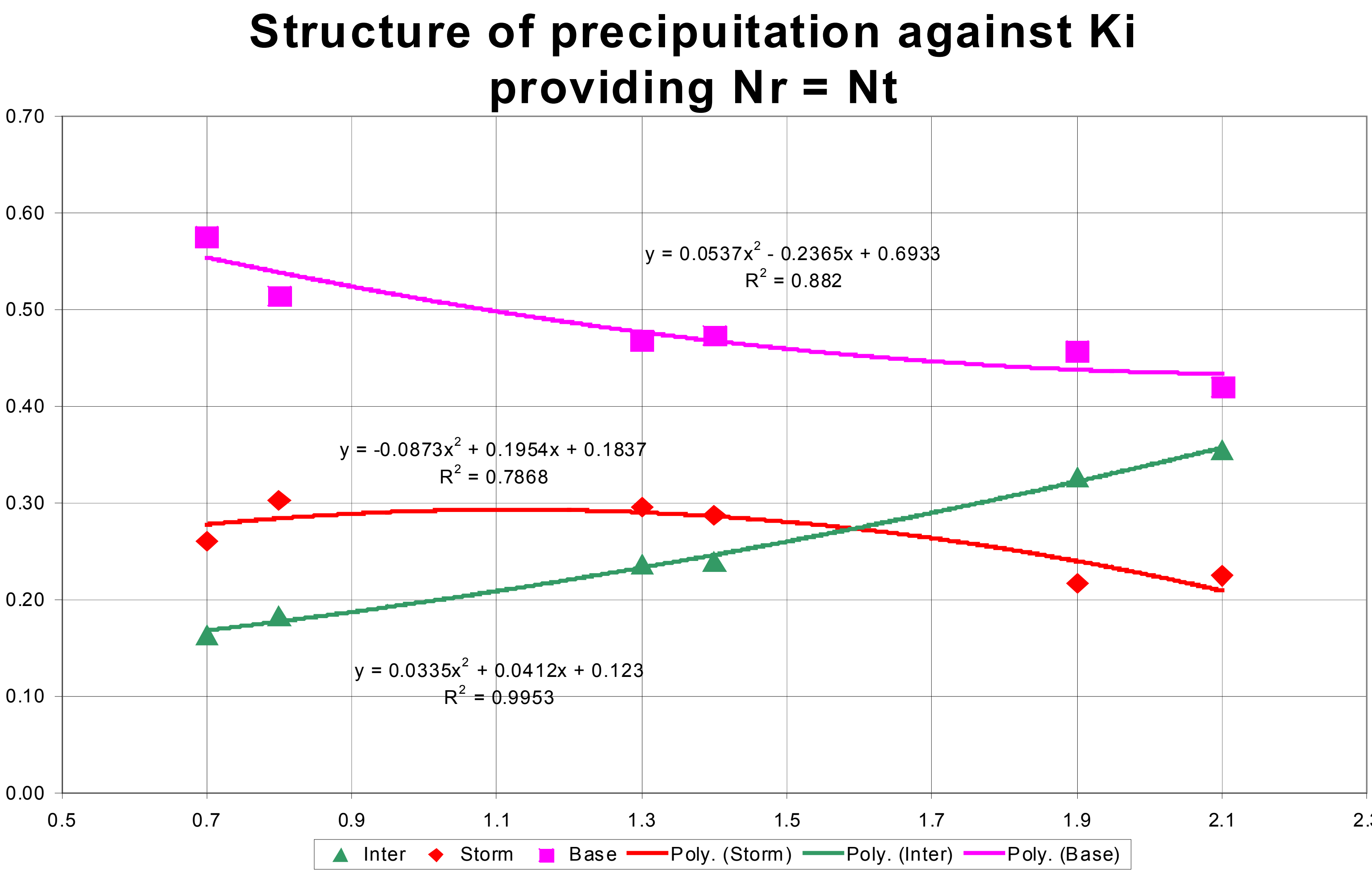
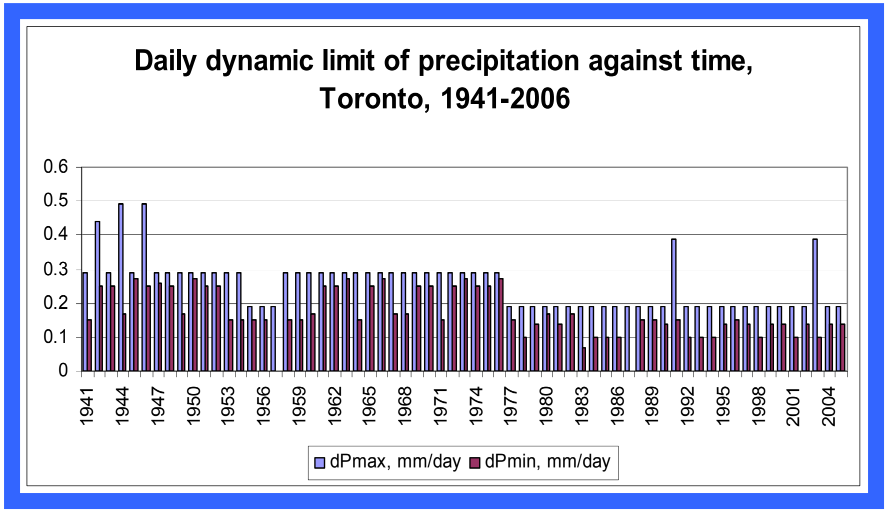
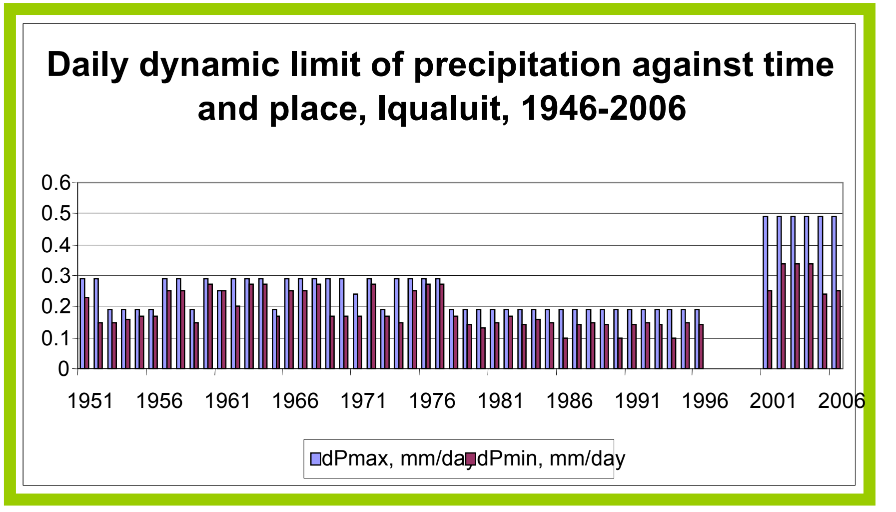
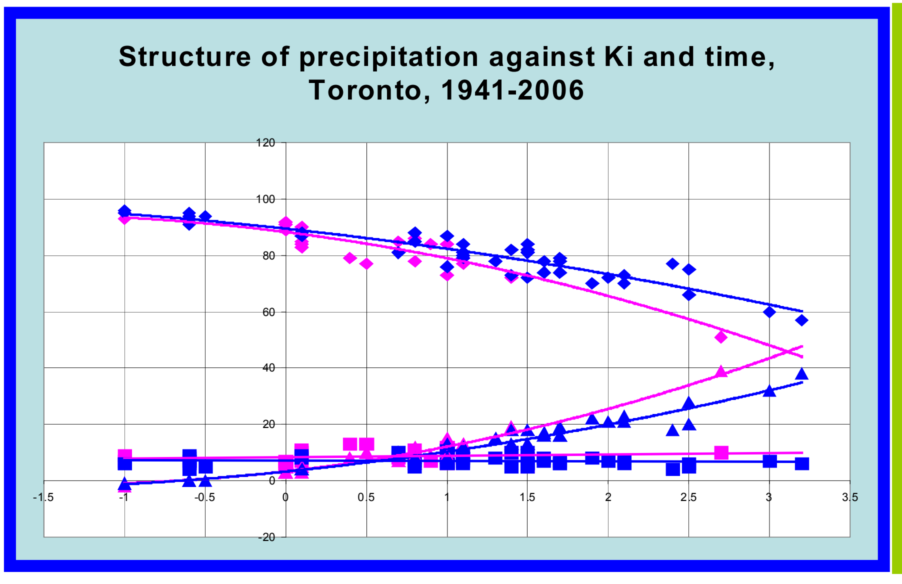
“Operation graph” of the continental hydrosphere: Canada total, 1995-2000

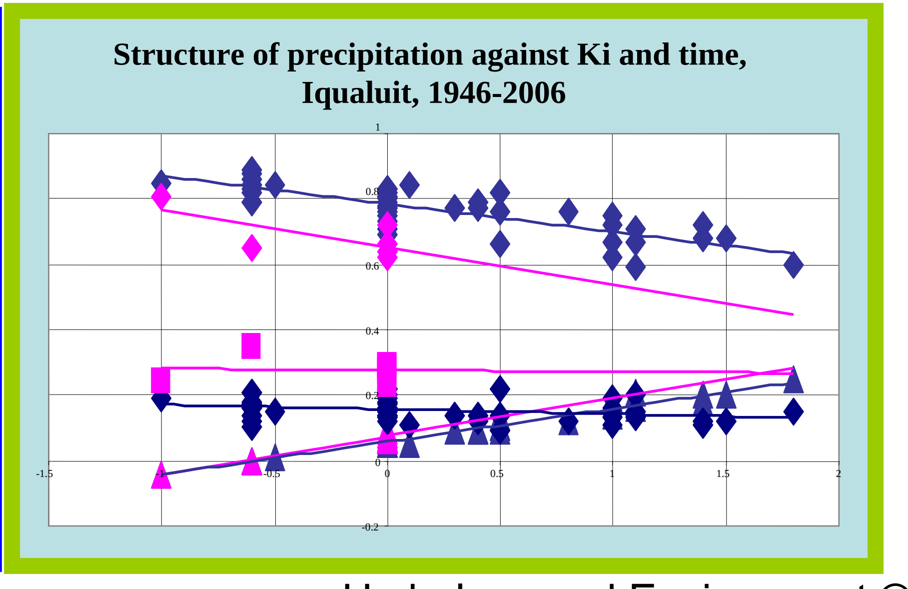


Precipitation: Toronto -Iqualuit









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Resolutions comparison
Toronto Airport, 2006

Daily resolution

Parameter	dQ	units	N	N/month
Temperature, °C	1.09	grad/day	59	5
Stn Press (kPa)	0.19	kPa/day	59	5
Visibility (km)	2.49	km/day	59	5
Wind Dir (10's deg)	1.50	10's deg/ day	69	6
Rel Hum (%)	4.86	%/day	71	6
Precipitation	0.19	mm/day	75	6
Wind Spd (km/h)	0.51	m/s/day	80	7
AQI	1.70	units/day	83	7

Hourly resolution

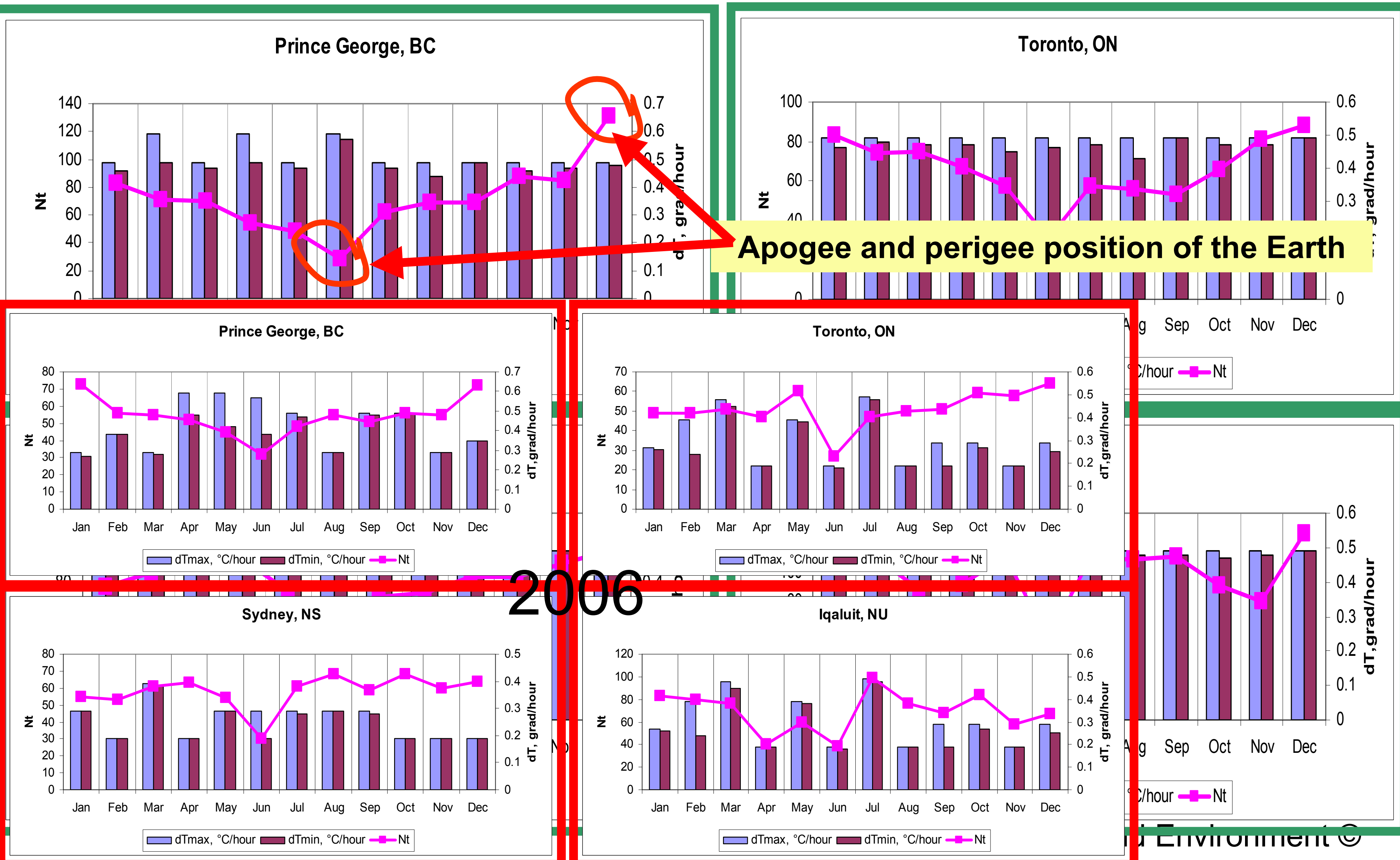
Parameter	dQ	units	N	N/day
Stn Press (kPa)	0.019	kPa/hour	447	1
Visibility (km)	1.59	km/hour	506	1
Temperature (°C)	0.29	°C/hour	610	2
Rel Hum (%)	1.99	%/hour	877	2
Wind Dir (10's deg)	1.99	10'sdeg/hour	1217	3
Wind Spd m/s	0.55	m/s/hour	1803	5

Qualitative parameters have higher frequencies than quantitative ones

Changing of resolution reveals

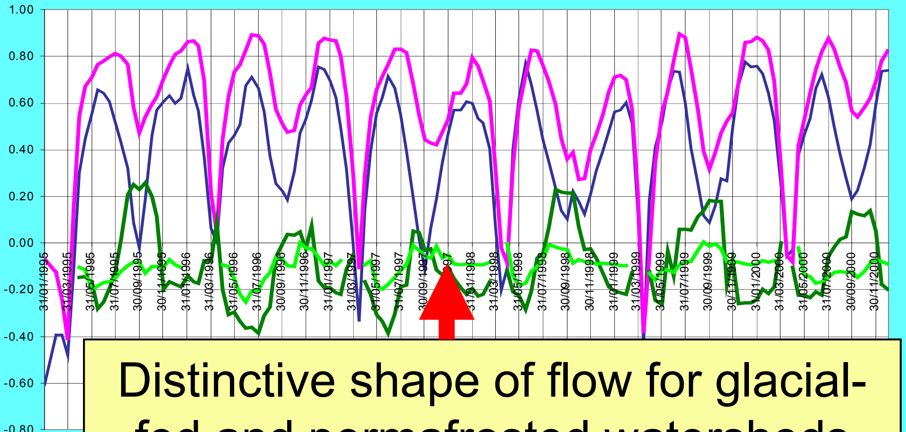
- Different roles of parameters at different scales
- Higher resolutions require higher sensitivity of measurement tools
- Sensitivity threshold for precipitation (traces) can be estimated using SFA part 2

Hourly limits dT and frequencies Nt of temperature in 1953 and 2006

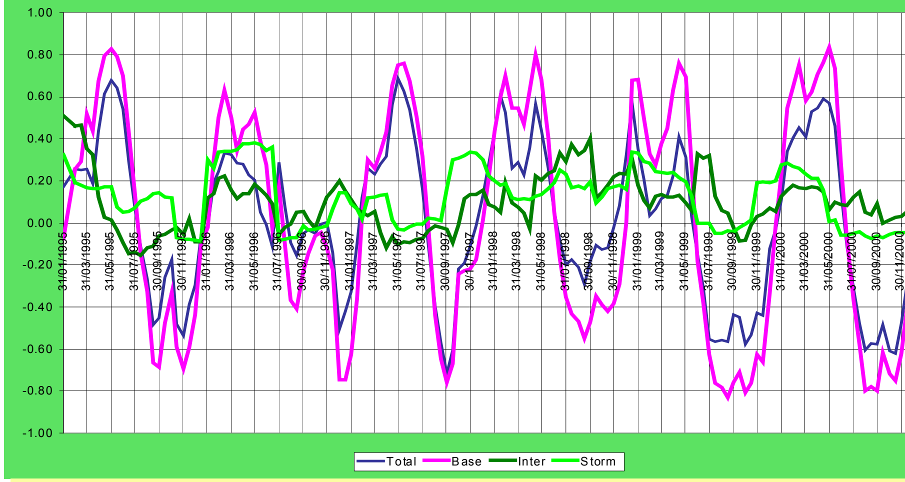


Controversial semi-annual correlation between different flow components and temperature

Omineka R., BC, 5470 km2

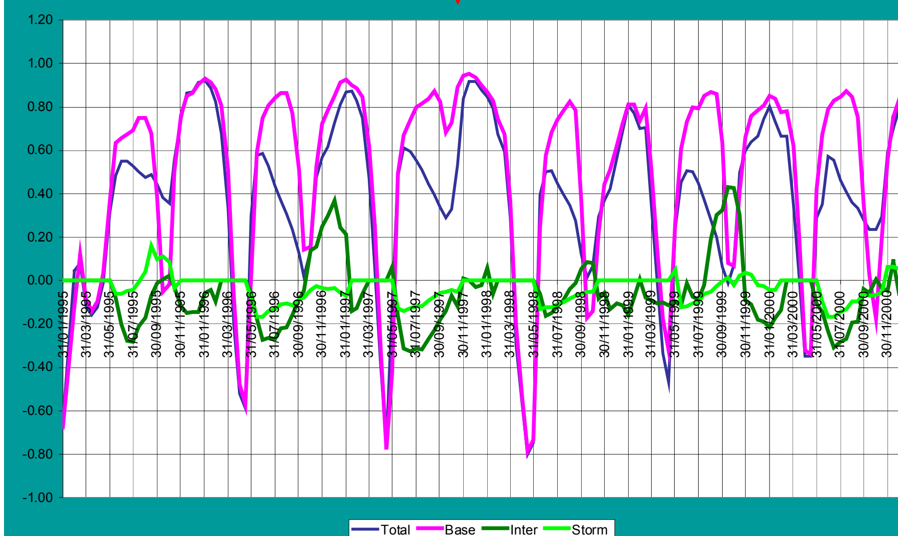


Harris R., NF, 640 km2

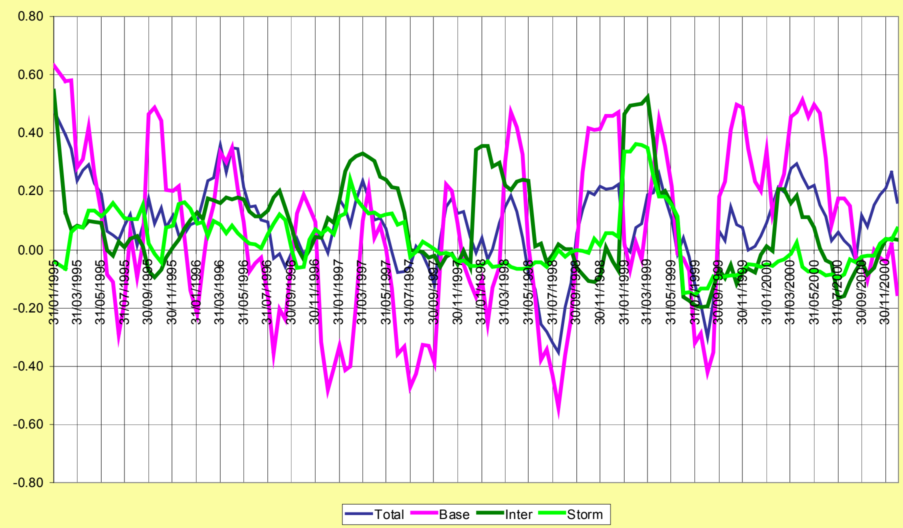


Distinctive shape of flow for glacial-fed and permafrosted watersheds

Thelon R., NU, 65 600 km2



Turkey R., ON, 29.4 km2



SFA, part 3: feedback functionality

Omineka R., BC, 5 470 km2

Ranged average		Ranged ABS average	
0.35	Total	0.42	Total
0.32	Inter	0.41	Base
0.31	Base	0.40	B_Temperature, °C
0.30			
0.29			
0.27			
0.26			
0.24			
0.24			
0.23			
0.02			
0.00			

Harris R., NF, 640 km2

Ranged average		Ranged ABS average	
0.29	Total	0.29	Total
0.29	P_total, mm	0.29	P_total, mm
0.27	P_inter, mm	0.28	P_inter, mm
0.25	Int		
0.24	P_s		
0.22	Sto		
0.18	P_		
0.18	T_		
0.16	Ba		
0.16	S_		
0.16	I_T		
0.12	B_		

Thelon R., NU, 65 600 km2

Ranged average		Ranged ABS average	
0.37	T_Temperature, °C	0.43	B_Temperature, °C
0.35	B_Temperature, °C	0.40	T_Temperature, °C
0.34	Total	0.38	Base
0.32	P_total, mm	0.38	Total
0.29	Base	0.36	P_total, mm
0.29	P_inter, mm	0.32	P_inter, mm
0.29	Inter	0.32	Inter
0.27	P_storm,mm	0.30	P_storm,mm
0.23	P_base, mm	0.27	P_base, mm
0.23	Storm	0.24	Storm
0.02	I_Temperature, °C	0.23	S_Temperature, °C
0.02	S_Temperature, °C	0.23	I_Temperature, °C

Turkey R., 29.6 km2

Ranged average		Ranged ABS average	
0.41	Total	0.41	Total
0.38	P_total, mm	0.38	P_total, mm
0.36	P_storm,mm	0.36	P_storm,mm
0.36	Inter	0.36	Inter
0.36	P_inter, mm	0.36	P_inter, mm
0.35	Storm	0.35	Storm
0.33	P_base, mm	0.34	P_base, mm
0.20	Base	0.22	Base
0.20	T_Temperature, °C	0.21	B_Temperature, °C
0.18	I_Temperature, °C	0.21	T_Temperature, °C
0.15	S_Temperature, °C	0.20	I_Temperature, °C
0.15	B_Temperature, °C	0.18	S_Temperature, °C

Fletcher's project results

SFA, part 1

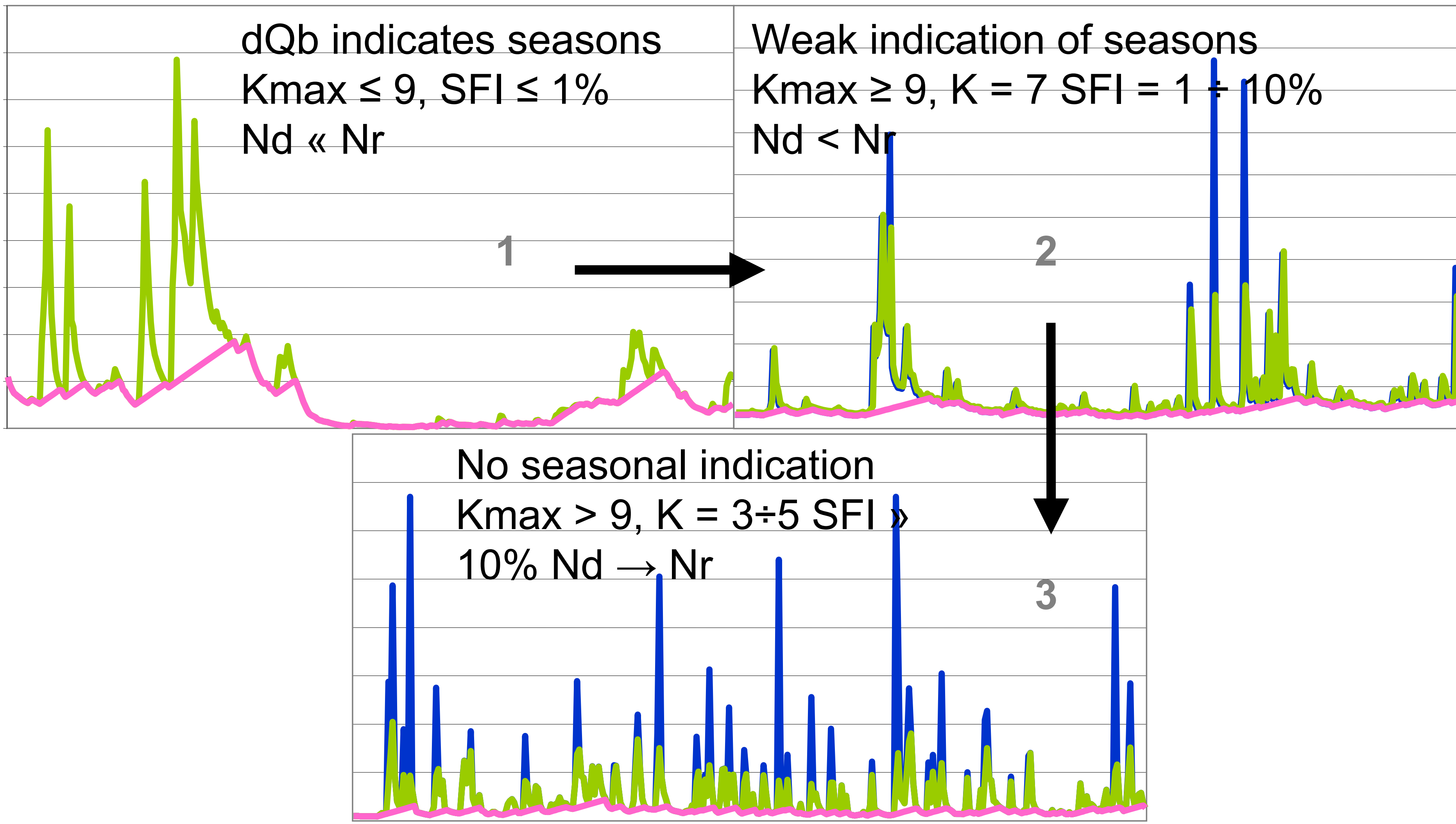
Parameter	Ground water			Surface water			Air		
	dQ	N	Kmax	dQ	N	Kmax	dQ	N	Kmax
pH	0.099	13	1	0.099	13	1	n/a	n/a	n/a
Turbidity, NFU/ Humidity, %	0.09	10	2	0.67	16	7	3.4	14	2
Temperature, °C	0.2	8	1	0.99	12	1	1.09	9	2
Level, cm/ Precipitation, mm	0.9	6	2	0.49	10	3	0.02	14	7
TDS, g/L/ AQI	0.043	6	2	0.031	7	1	3.4	14	2
Velocity, m/s/ Wind, m/s	n/a	n/a	n/a	0.004	11	6	3.9	17	1

SFA, part 4

Average		ABS Average	
0.132	Flow_T	0.581	TDS_B
0.129	Velocity_T	0.580	TDS_I
0.123	Turb_T	0.580	TDS_T
0.123	Turb_I	0.579	Flow_B
0.121	Flow_I	0.572	Level_T
0.120	Velocity_I	0.572	Level_I
0.116	S/level_T	0.570	Velocity_B
0.097	Prec_T	0.568	Level_B
0.091	Prec_I	0.559	S/level_B
0.089	Prec_B	0.553	Air_B
0.082	S/level_I	0.550	Air_I
0.077	Wind_I	0.549	Air_T
0.076	Wind_T	0.547	Travel_T
0.075	Humid_B	0.546	pH_B
0.065	Humid_I	0.546	Travel_I
0.065	Humid_T	0.542	S/level_I
0.060	Turb_I	0.531	pH_B
0.059	Turb_T	0.527	Water T_B
0.057	pH_I	0.526	pH_I
0.056	Wind_B	0.524	Turb_B
0.056	pH_T	0.524	pH_T

- The most reactive/sensible parameter for GW is pH; for the stream water it is turbidity; in atmosphere this is wind.
- The highest priority parameter of the Fletcher's creek is the groundwater TDS.

Hydrological identification of urbanization using the SimpleBase Model



BFINDEX and the SimpleBase Model comparison

The model for 7Q2 predicting based on 38 stations of S. Ontario*:

available in the article below (1)

BFINDEX: R^2 = 90%; SE = 0.43 (3 stations are excluded)
SimpleBase: R^2 = 92%; no station is excluded

A new equation of 7Q2 estimation for the whole area was developed based on the SimpleBase Delineation Model parameters:

$$7Q2 = 37 \cdot 10^{-5} \cdot Area^{0.91} \cdot BFI^{2.65} \cdot Kmax^{0.29} \cdot Nd^{0.92} \quad (2)$$

R^2 = 96%; no station excluded

Where

Kmax – structural divider (amplitude);
Nd - frequency of baseflow fluctuation

*"Regional Low Flow Frequency Relations for Central Ontario" by Robert K. McLean and W. Edgar Watt, Canadian Water Resources Journal, Vol. 30, No 3, 2005

Kind of conclusion

- The function of water to regulate atmospheric and surface temperature named Elasticity of Hydrosphere can be seen at any point and time
- **It gives clear vision for sustainable water management**
- The Separated Flux Analysis and the SimpleBase Delineation Model as a heard of it is a right tool for water functionality assessment of any parameter of hydrosphere at any point