Geological Control on Water Resources Variability in Minnesota, U. S. A.

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SDSU

UMD DULUTH Reaching higher

UNIVERSITY OF MINNESOTA

Topics

- An introduction:
  Map is an universal media to reflect the time spatial distribution of water resources (WR)
- Model & analysis of WR distribution:
  geology in MN landscapes & water balance of watershed
- Types of data (hydrologic, numeric & classification) & analysis to eliminate the influence of climate change
- Research results:
  main patterns of stream flow & seasonality of stream flow
- Map of WR as result of statistical analysis of landscape originated layers & role of geology & hydrogeology in controlling maps' boundaries
- Map of WR & analysis of regime – the way to include climate influence to monitoring & manage WR
- 2009 year of Science.
  For discussions: The hydrological structure in landscape

Map of Water Resources & Wars over Water – Introduction

The WR map has to be the base with the numbers for sustainable water management

NATIONAL WILDLIFE

National Wildlife Federation

Oct/Nov 2009, vol. 47 no. 6

Issue home | See past issues

Conservation

By Doreen Cubie

The Water Wars Move East

As states in the Southeast fight over limited water resources, conservationists struggle to keep the region's river flows high enough to sustain wildlife

Environ Geol (2009) 58:1441–1450
DOI 10.1007/s00254-008-1646-9

ORIGINAL ARTICLE

Sustainability of groundwater in Mali, West Africa

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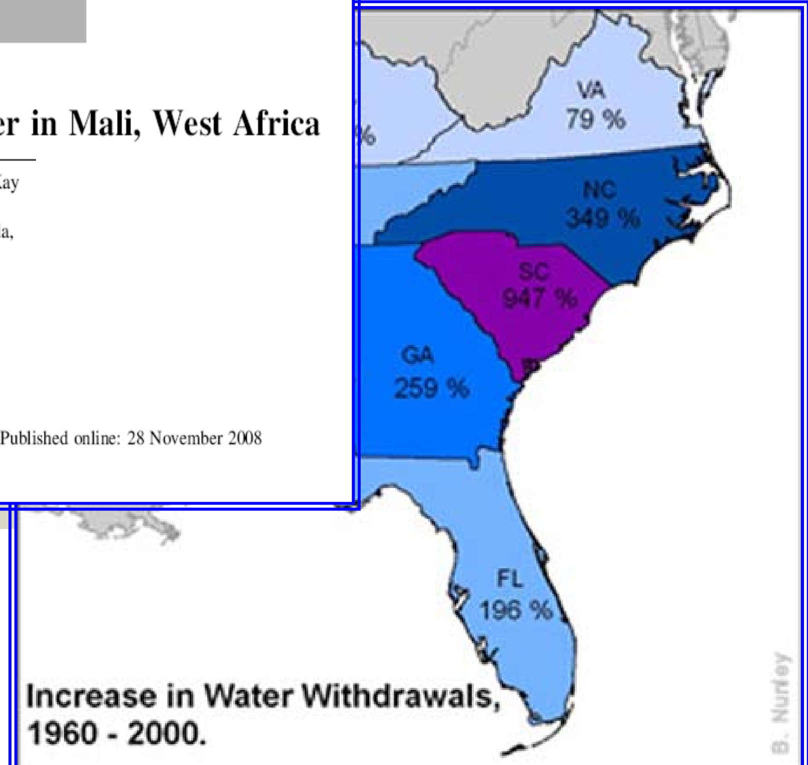


Do nations go to war over water?

Wendy Barnaby was asked to write a book about water wars — then the facts got in the way of her story.

The United Nations warned as recently as last week that climate change harbours the potential for serious conflicts over water. In its World

Allan had made the same assumption a few decades earlier when he set out to study the water situation in Libya. By the mid-1980s,

literate younger generation, would catch on better than his own term. And he was right: "From there on it flew," he says.

Water Resources Development,
Vol. 24, No. 2, 201–215, June 2008

Routledge
Taylor & Francis Group

Wake Up to Realities of River Basin Closure

MALIN FALKENMARK* & DAVID MOLDEN**
*Stockholm International Water Institute (SIWI), Stockholm, Sweden; **International Water Management Institute (IWMI), Colombo, Sri Lanka

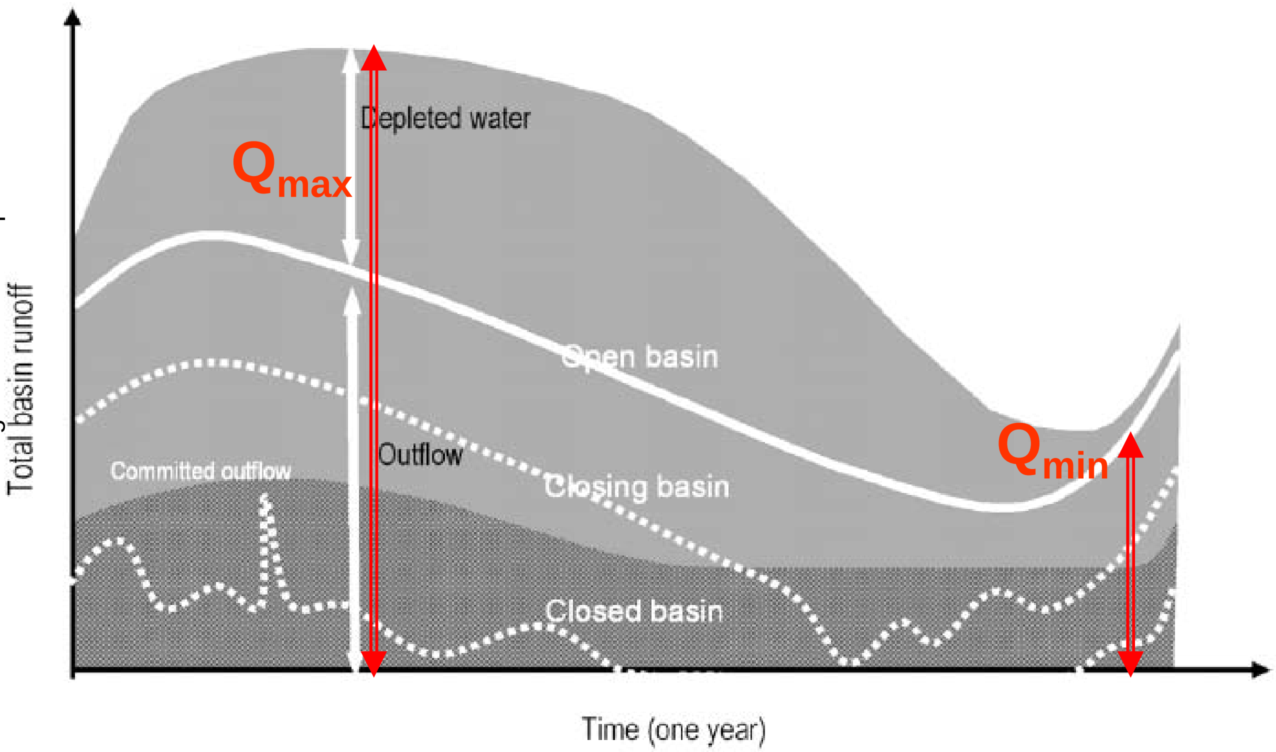
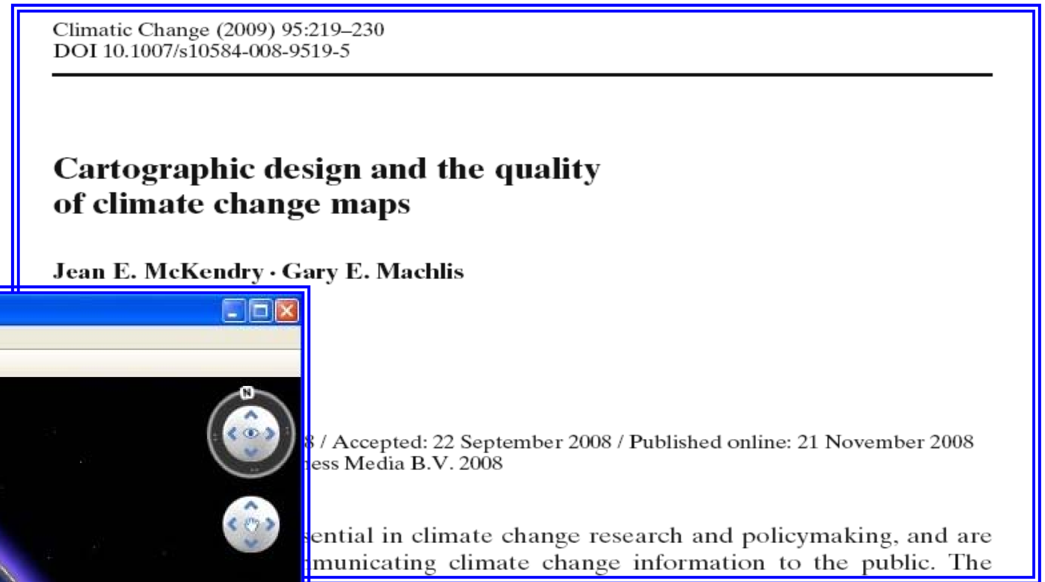


Figure 1. The process of closure over time. In open basins more water can be allocated and diverted, while in a closed basin, flows are over-allocated and diversions of water have impacts on the levels committed for environmental flows and downstream users. *Source:* From Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture (http://www.earthscan.co.uk)

Do we know the time spatial variability of water resources ? For Minnesota…

The hydrograph represent the river discharge & reflect annual variability. The monthly max & min discharge (Q_{max} & Q_{min}) are significant characteristics for hydrograph

Water Resources map for MN

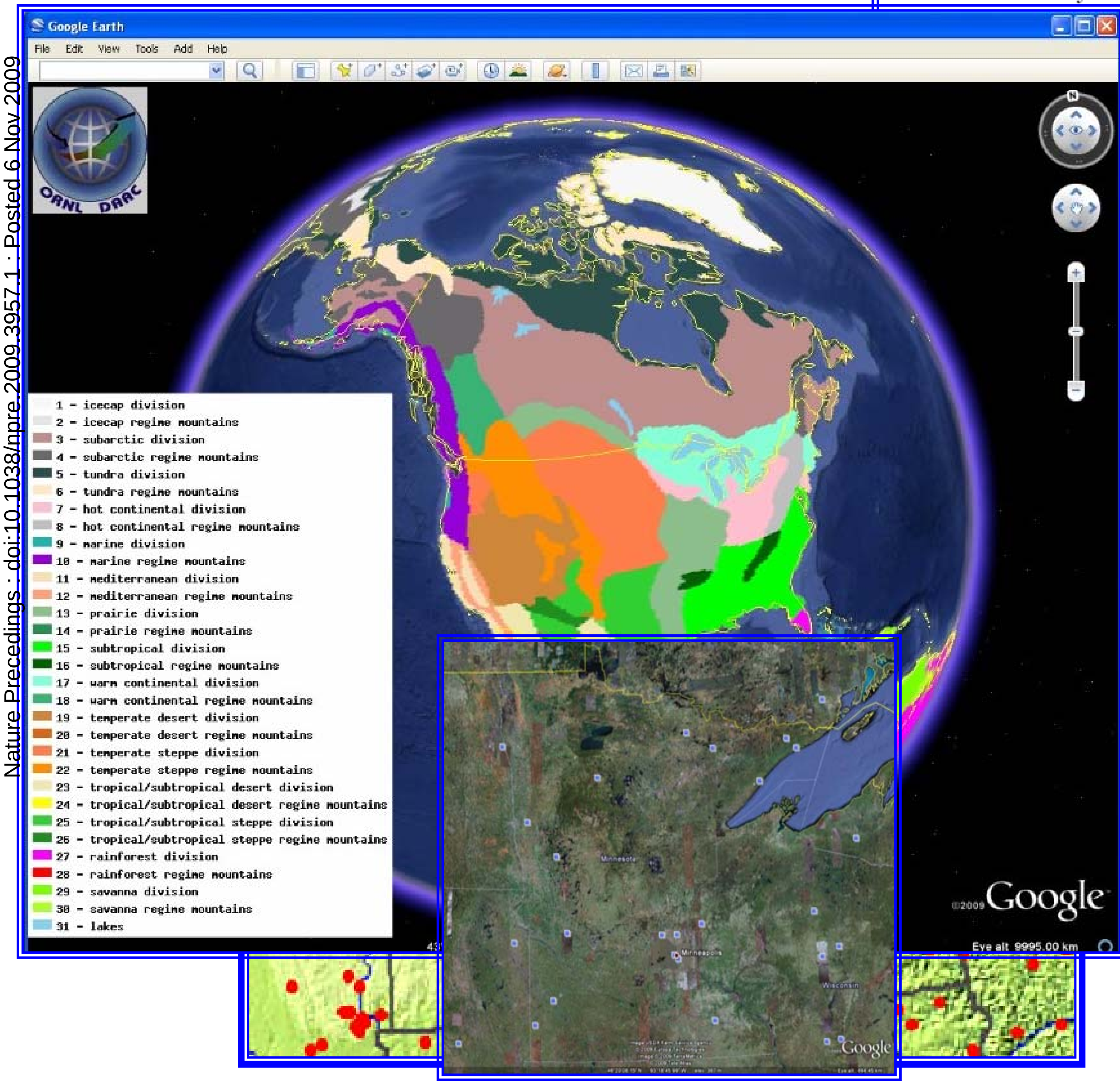

Climatic Change (2009) 95:219–230
DOI 10.1007/s10584-008-9519-5

Cartographic design and the quality of climate change maps

Jean E. McKendry · Gary E. Machlis

8 / Accepted: 22 September 2008 / Published online: 21 November 2008
ess Media B.V. 2008

ential in climate change research and policymaking, and are
municating climate change information to the public. The



The topography map is useful tool for scientists
&
in daily life for everybody

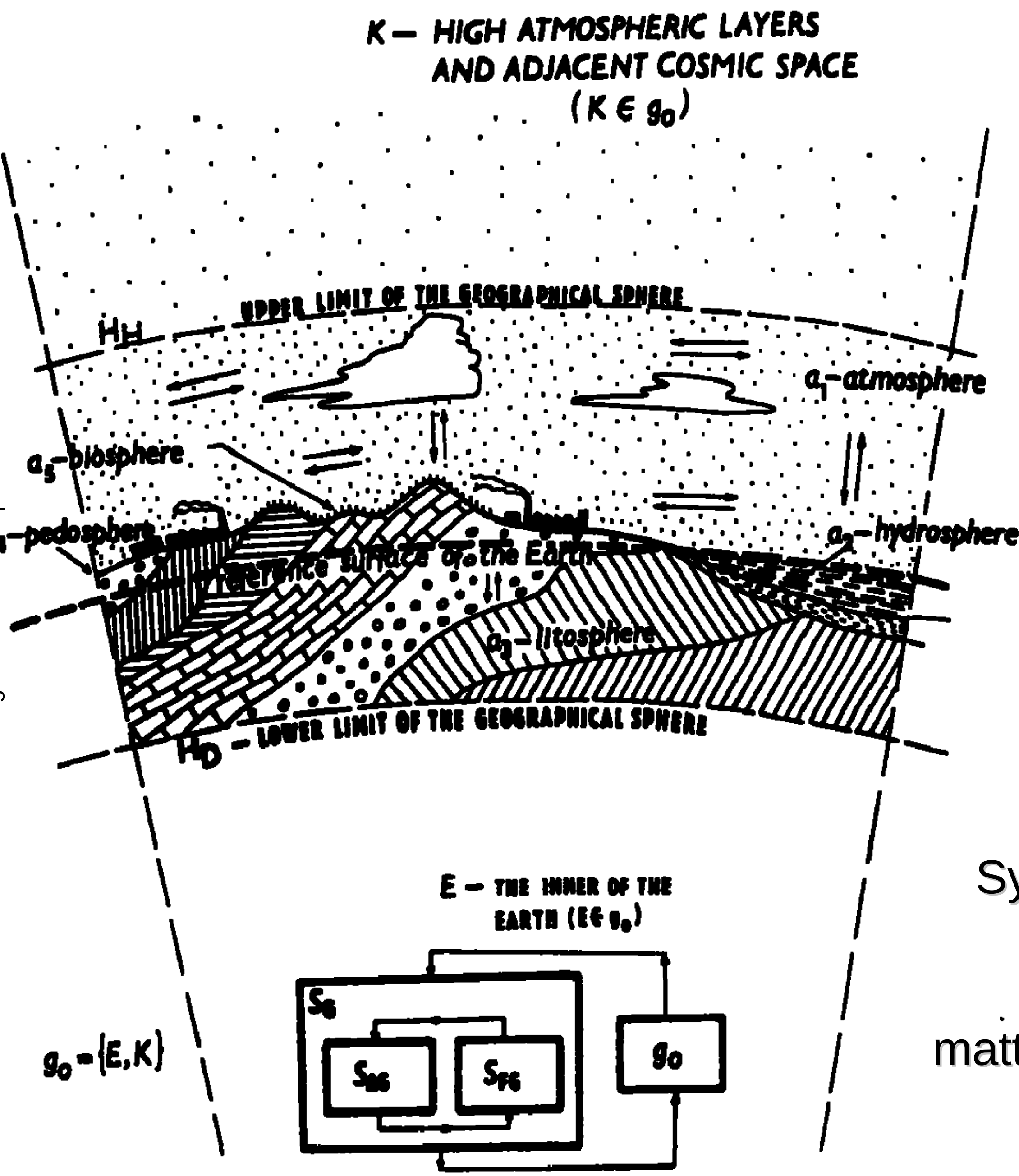
Placed on Google Earth the WR resources map will became a useful source of quantity information for scales & levels from country & state to county & small town community

Topic

Model & analysis of stream flow distribution:

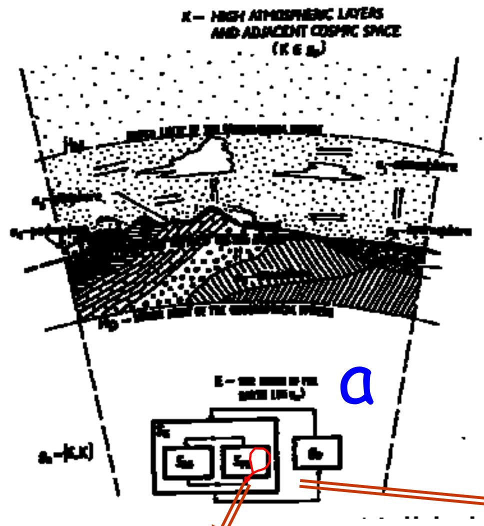
geology in MN landscapes & control of water cycle

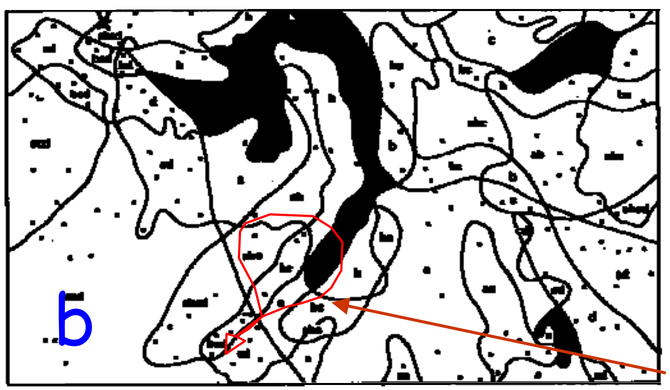
Model of 3D watershed in landscape



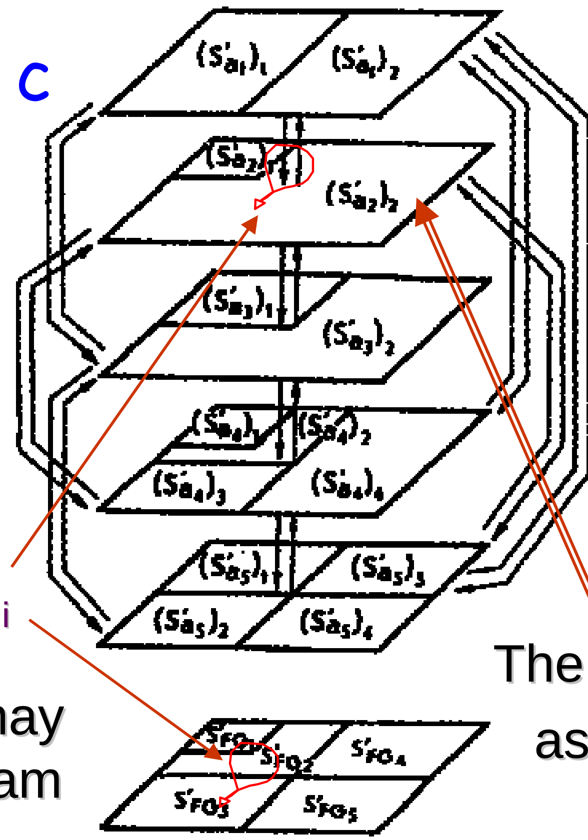
Vertical slice of the Geographical Sphere with two independent elements: System of Anthropological Geography (S_{AG}) & System of Physical Geography (S_{FG}). Arrows indicate vertical & horizontal components of matter, energy & information circulating (after Krcho, 1978)

System model (a) for watershed in landscape, with map of conditions (b) & multilayer Map (c)





g_{ji}



System of Physical Geography Sphere (S_{FG}) with five independent elements:
a_1- atmosphere,
a_2- hydrosphere,
a_3- lithosphere,
a_4- pedosphere,
a_5- biosphere.

The g_2 - stream runoff system as a part of a_2- hydrosphere may be presented as:

$Sg_2 = \{ g_{ji}, R_{ji} \}$,

where g_{Ji}- watershed.

Any watershed g_{ji} for territory may be considered as a part of stream runoff system Sg_2.

Each of these components may be characterized by matrix of input {Wi}, matrix of output {Qi}, & matrix of states {Hi}.

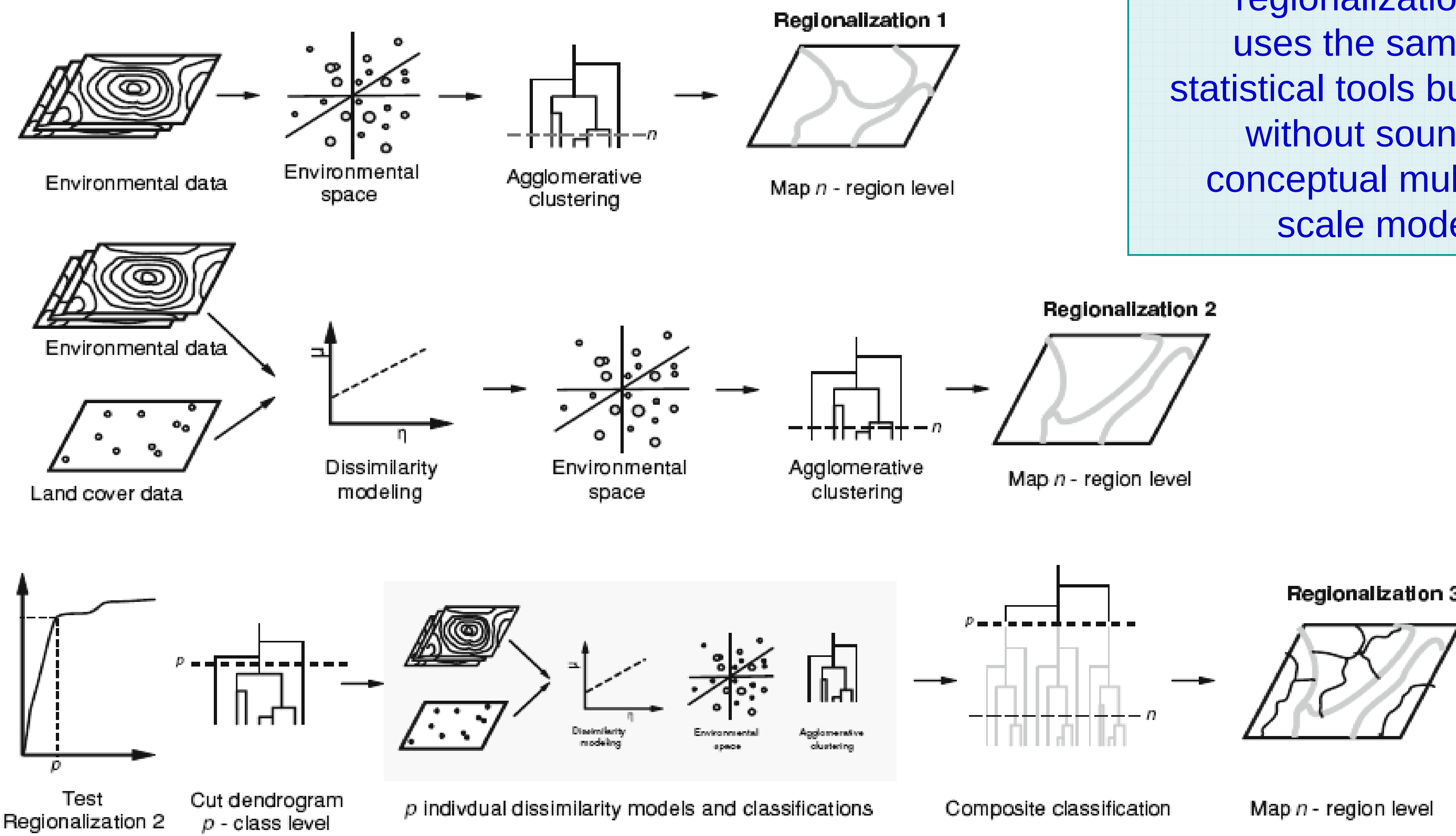
Environmental Management (2009) 44:658–670
DOI 10.1007/s00267-009-9352-2

Ecological & (or) landscape regionalization

Strong Influence of Variable Treatment on the Performance of Numerically Defined Ecological Regions

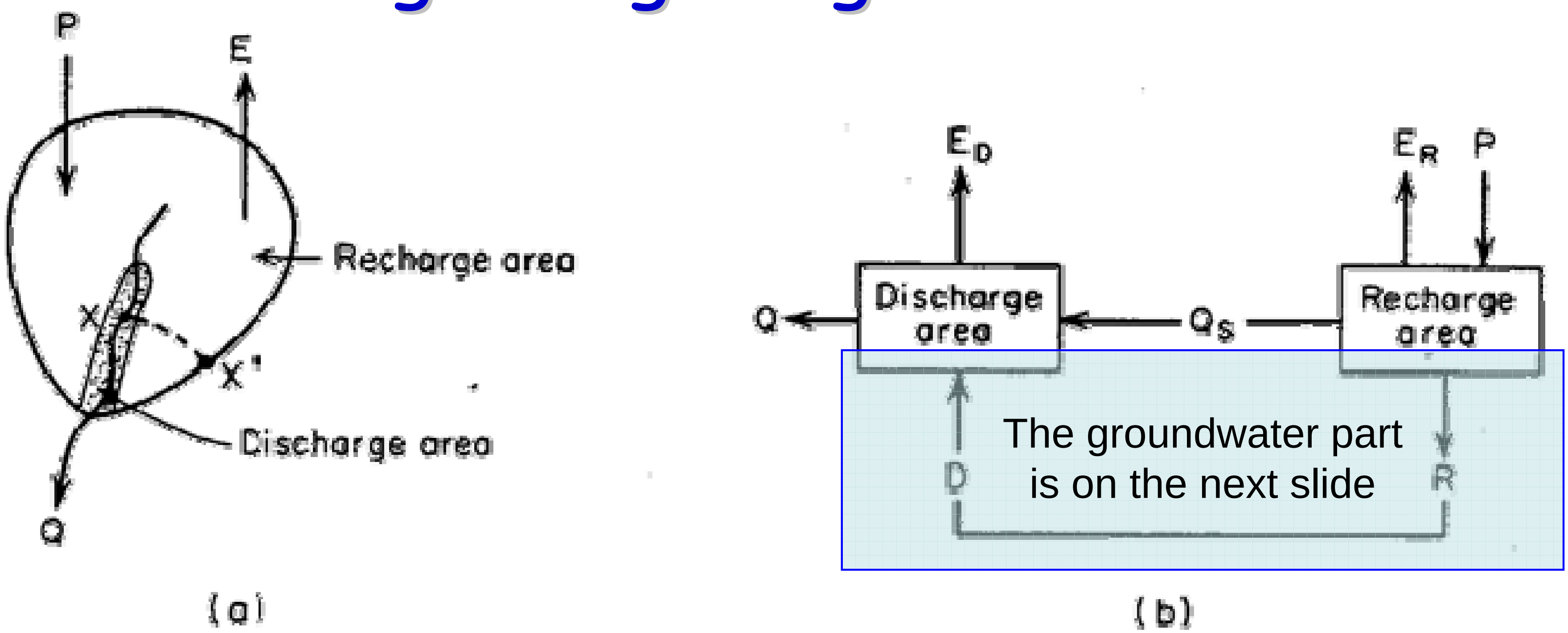
Ton Sn
John L

Ecological regionalization uses the same statistical tools but without sound conceptual multi scale model

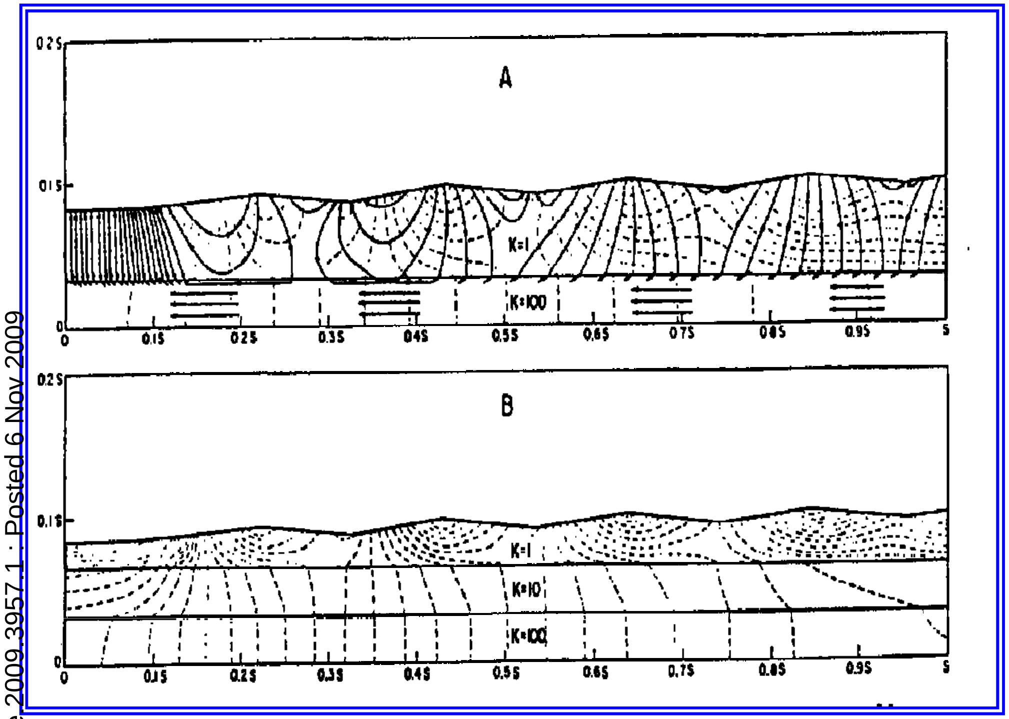


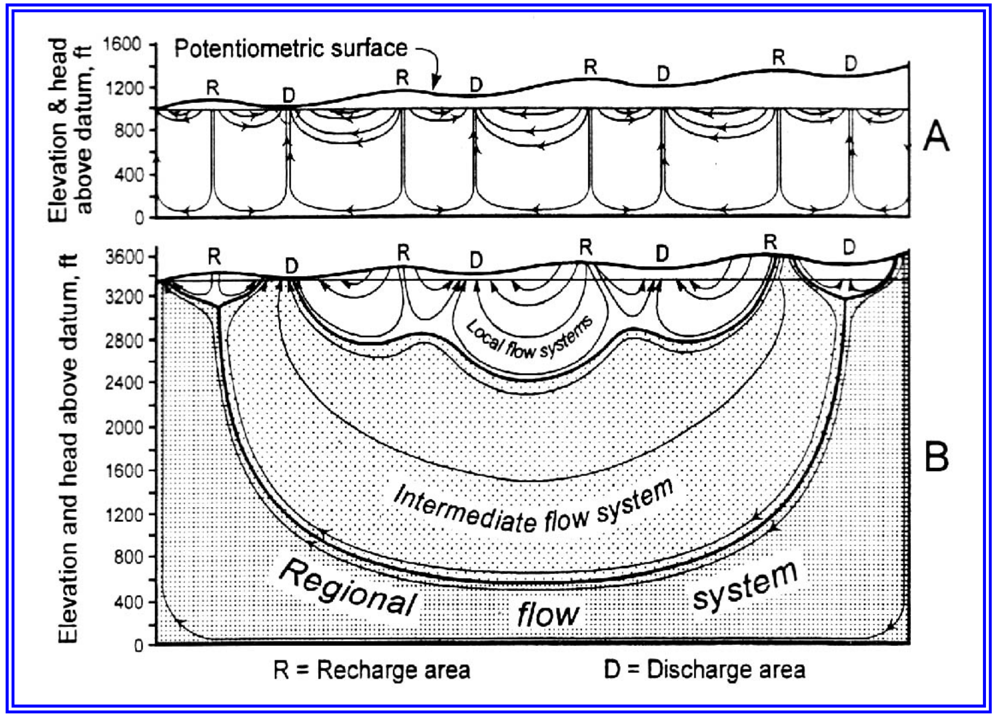
Schematic description of the procedures used to define the three ecological regionalizations

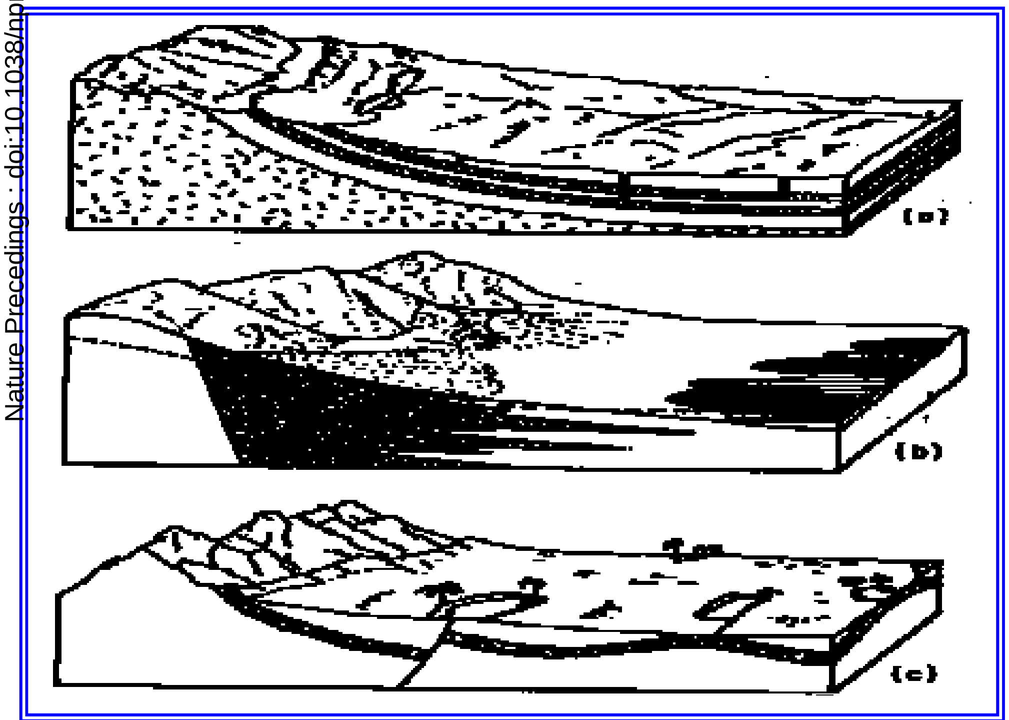
Watershed water balance must be related to a region's geological conditions



Elements of watershed water balance:
P- precipitation, E- evapotranspiration, Q- runoff, Q_s- the surface water component of average annual runoff, E_R- the average annual evapotranspiration from recharge area, E_D- the average annual evapotranspiration from discharge area, R- the average annual ground water recharge, D- the average annual ground water discharge;
X--X'- cross-section from shown in (b) - quantitative flow net & recharge-discharge profile in a two-dimensional section across the heterogeneous groundwater basin (after Freeze and Cherry, 1979)



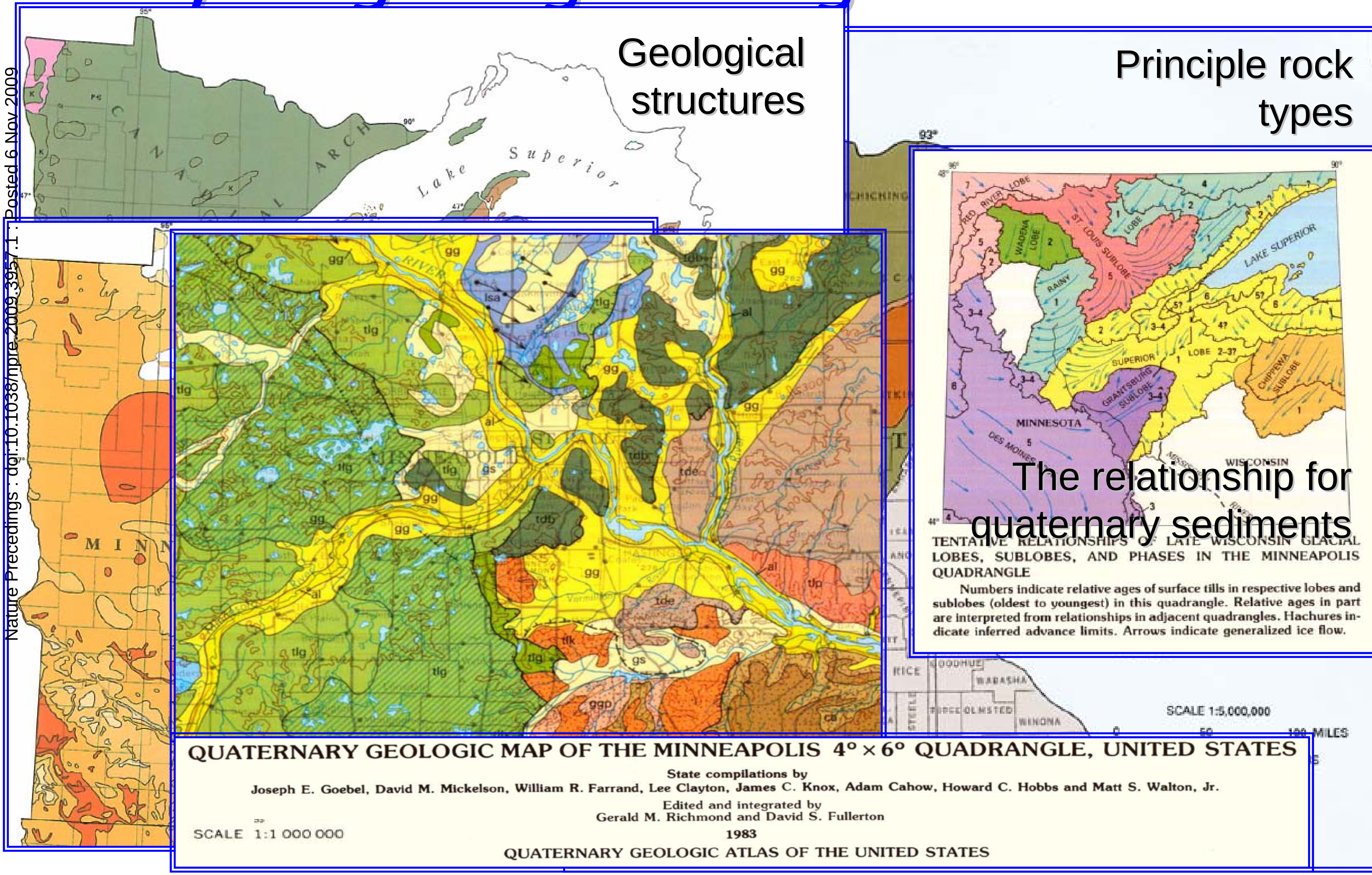




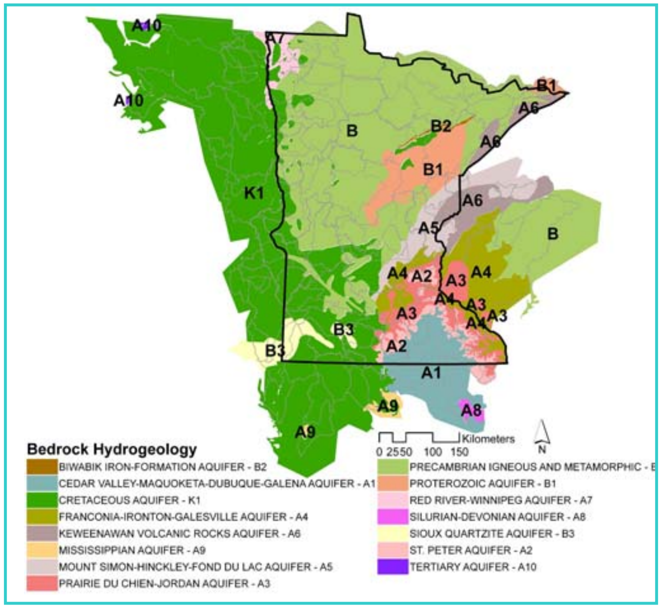
Cross-sections for
different hydrogeological settings,
showing the influence of stratigraphy
and structure on regional aquifer
occurrence
(after Freeze and Cherry, 1979)

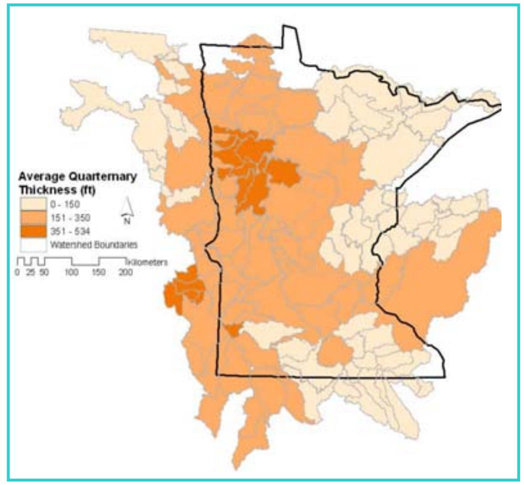
3th dimension for watershed

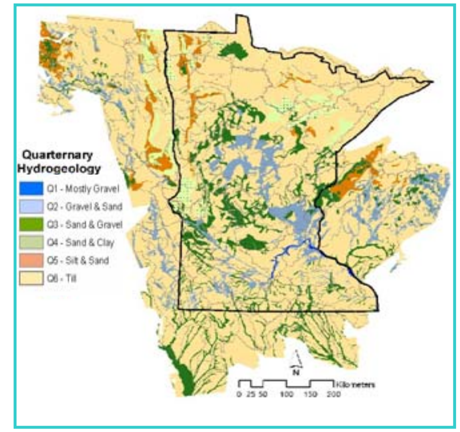
Geological maps & hydrogeological regionalization

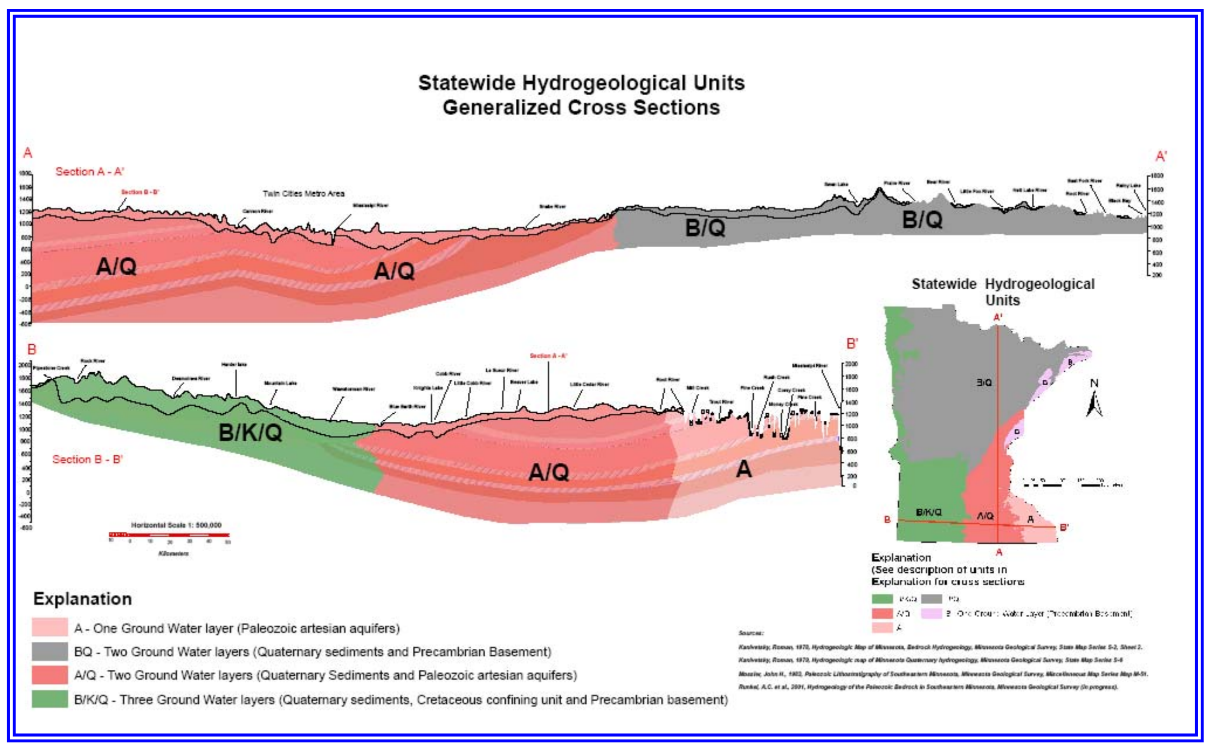


Maps for hierarchical hydrogeological regionalization



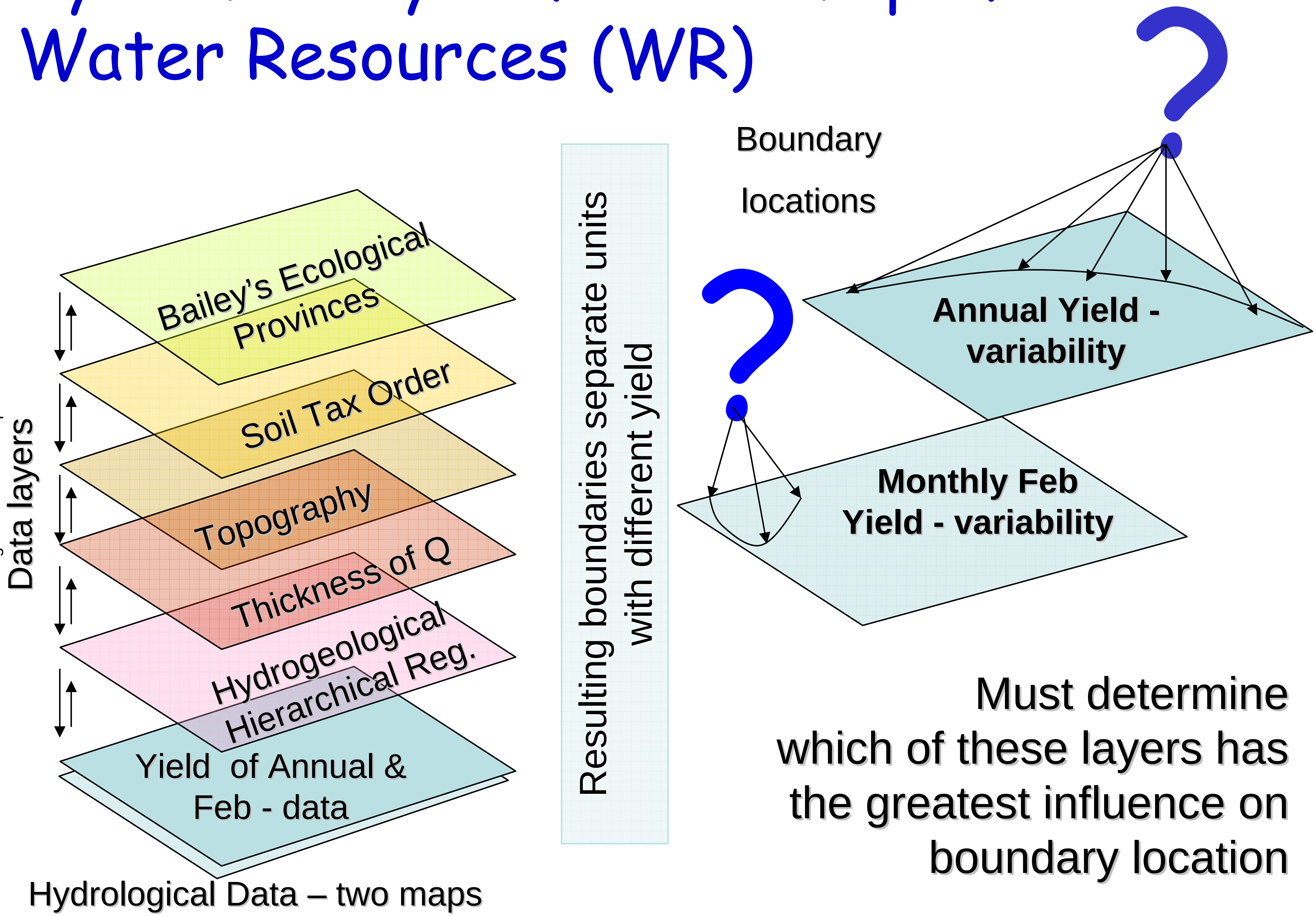






Geological maps must used from for Hierarchical Hydrogeological (HH) regionalization

System analysis for the map of Water Resources (WR)



Must determine which of these layers has the greatest influence on boundary location

Topic

Data

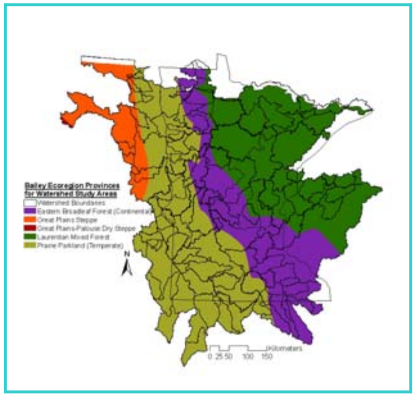
(hydrologic, numeric & classification)

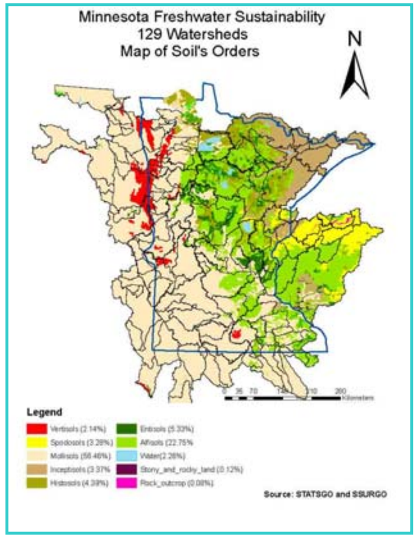
&

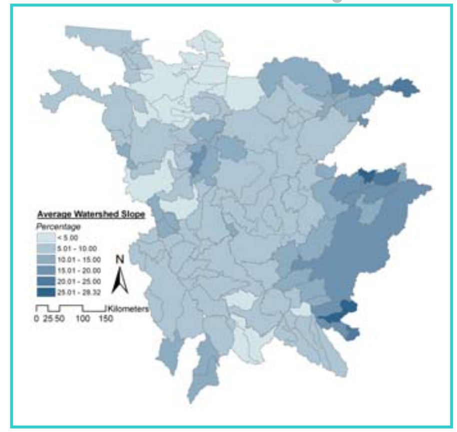
analysis to eliminate the influence of climate change

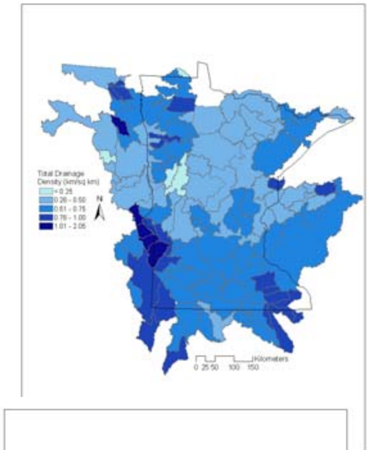
(stationary approach)

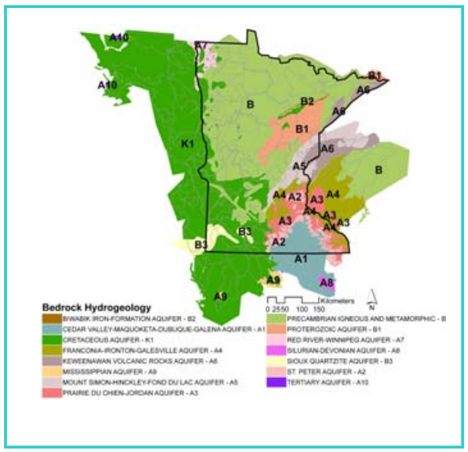
Data of conditions on maps & yield

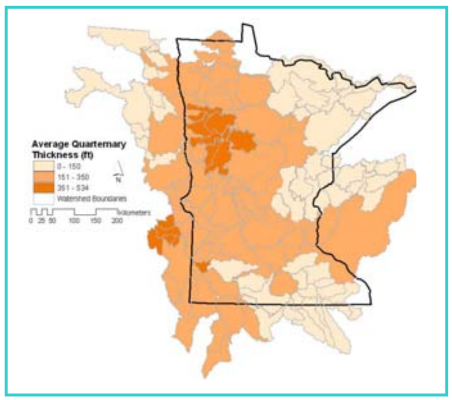


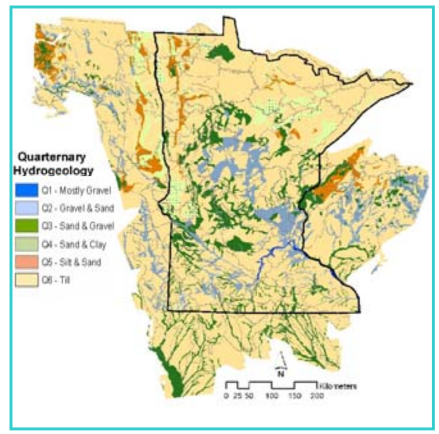


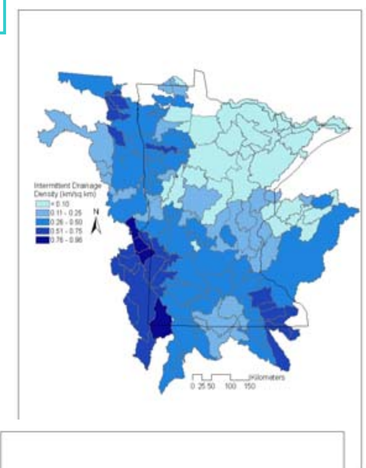


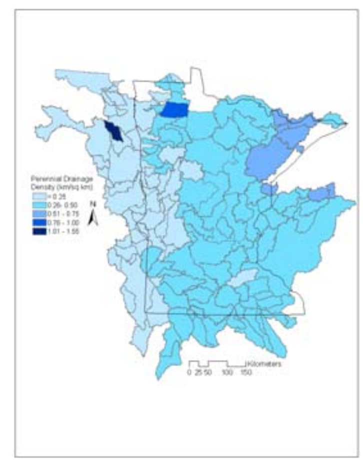


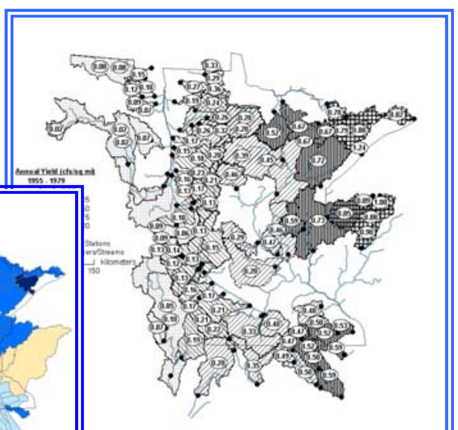


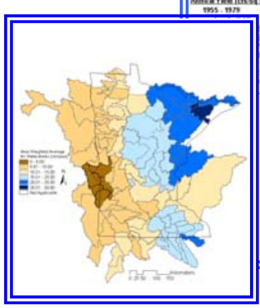












Only water resources (yield) must be created by performing system analysis; all other data sources already exist

SCIENCE VOL 319 1 FEBRUARY 2008
Published by AAAS

CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

P. C. D. Milly,[1*] Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

To complete research for WR map
The "Main patterns of stream flow" &
"Seasonal distribution of stream flow"
must be discovered & described

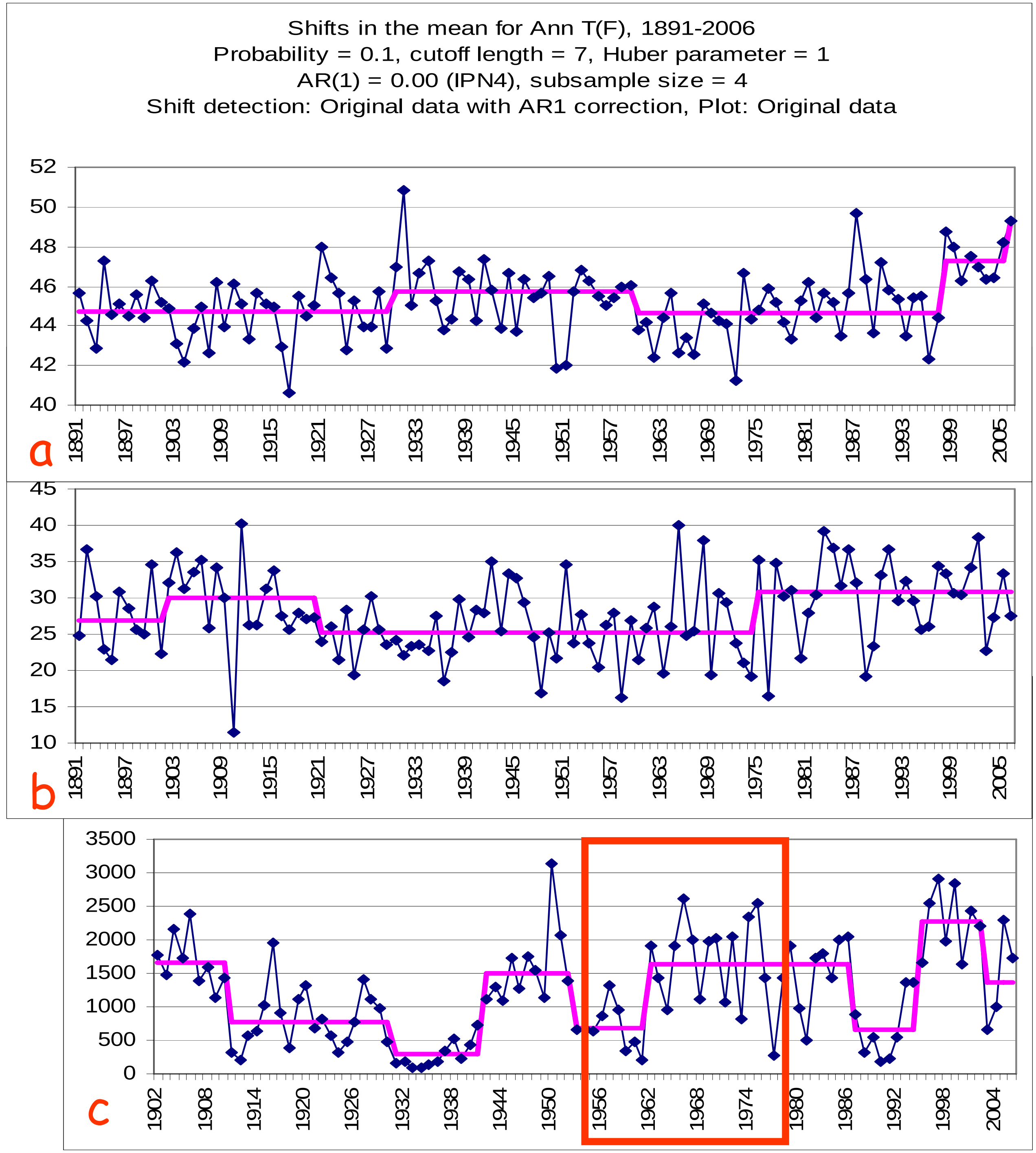
System analysis of WR in MN

Table of research tasks, models, initial & results matrix

Group of tasks	Research level	Initial matrix $X_{(t,n)*p}$		Statistical method	Matrices of results	Final graphics & equations
		Rows ***t, n***	Columns ***p***			
1. Identification and mapping of patterns of multi-year annual regime variability (stream runoff, air temperature, precipitation) for set of watersheds or stations	Global Regional Basin	Years	Time series (TS) of discharge $\{Q_{j*i}\}$ temp.$\{T_{j*n}\}$ and $\{W_{j*n}\}$ – precip.	Factor, Time serries and Cluster analyses	A_{p*k} – dimensions of process, grouping by types of regime F_{k*t} – components for types of regime Ed - distances for watersheds and observation years.	Map of multi-year variability patterns. Component curves of patterns and smoothed component curves. Dendrograms of observation years. Tables for time series parameters
2. Description of annual variability (dimension for intra-annual process, the most variable months and links with annual values) for runoff from watershed, ground water level (GWL) in wells and data from meteorological stations, trend analysis	Planet Global Regional Basin Station	Years	TS of discharge $\{Q_{j*12,13}\}$, level $\{H_{j*12,13}\}$, temperature $\{T_{j*12,13}\}$ and $\{W_{j*12,13}\}$ - precipitation	Factor, Time serries and Cluster analyses	A_{p*k} – dimensions of process, grouping by seasons regime F_{k*t} – components for seasons. Ed - distances for months and observation years	Scatterplots (2D and 3D) of connections in the planes of factors Component curves for annual and seasonal runoff and smoothed component curves, Tables for time series parameters Dendrograms of seasons and observation years
3. Establishment of association between multi-year runoff parameters and other state indices or attributes of landscape	Planet Global Regional Basin	Years	TS of discharge $\{Q_{j*i}\}$, and state indices $\{H_{j*i}\}$	Factor analyses & Step by step regression	A_{p*k} – structure of relations $Y=a_0+\sum_{i=1}^{m} a_i x_i + e$, - regression equation	Scatterplots (2D and 3D) of connections in the planes of factors. Regression equation with other state indices or attributes of landscape.
4. Description and mapping of regional features of seasonal average values for runoff, GWL and meteorological data	Global Regional Basin	Watersheds. Stations or well of observation.	Average values of runoff TS $\{Q_{j*i}\}$, $\{Q'_{j*i}\}$ and meteodata TS $\{T_{j*i}\}$, $W_{j*i}\}$	Factor analyses	A_{p*k} – dimensions as number of seasons and structure of relations of months in a season in a year F_{k*n} – location of watershed, well or station in each season	Scatterplots (2D and 3D) of unification months in seasons and in year in the planes of factors. Map of distribution watersheds, wells or stations with different seasonal pattern
5. Identification of relationship between surface and GW runoff parameters, min and max temperatures	Regional Basin	Watersheds	Runoff parameters $\{q_{j*i}, k_{j*i}\}$	Factor analyses	A_{p*k} – dimensions of process and structure of relations F_{k*n} – grouping of watersheds by generalized characteristics	Scatterplots (2D and 3D) of connection of runoff characteristics in the planes of factors Diagrams of distribution of watersheds by runoff characteristics in the planes of factors
6. Establishment of relationship between runoff parameters distribution and attributes of atmosphere and lithosphere components for watersheds	Regional Basin	Watersheds	Parameters of runoff and attributes of atmosphere and lithosphere conditions $\{q_{j*i}, k_{j*i}, T_{j*i}, W_{j*i}, H_{j*i}\}$	Factor analyses and Step by step regression	A_{p*k} – object dimensions and structure of relations of runoff with conditions of formation F_{k*n} – grouping of watersheds by generalized characteristics of runoff and conditions $Y=a_0+\sum_{i=1}^{m} a_i x_i + e$, - regression equation	Scatterplots (2D and 3D) of relations of runoff with conditions of formation in the planes of factors Scatterplots (2D and 3D) of distribution of watersheds by runoff and conditions of formation in the planes of factors Regression equation for characteristics of runoff from characteristics of conditions
7. Reevaluation and mapping of units with quazi-uniform landscape conditions (elements of regionalization), reevaluation of the influence on river runoff components (ground water and surface)	Regional Basin	Watersheds	Parameters of runoff and attributes of atmosphere and lithosphere conditions by elements of regionalization $\{q^h, k^h, H^h\}$	Factor analyses, Step by step regression, Student, Fisher and Nonparametric tests	A_{p*k} - structure or runoff parameters relations by elements of regionalization $Y=a_0+\sum_{i=1}^{m} a_i x_i + e$, - regression equation Table: Statistical criteria estimates of divisions by elements of regionalization	Scatterplots (2D and 3D) of relations of runoff with conditions of formation by elements of regionalization in the planes of factors Regression equation for parameters of runoff from attributes of conditions by elements of regionalization Maps of rivers and ground water runoff

Color shows the tasks completed in research part of creation a map

To eliminate climate change influence - use data for MN from mutual interval (1955-79)



Air temperature (Minneapolis) - a

Precipitation (Minneapolis) - b

Stream runoff (Red Lake River) - c

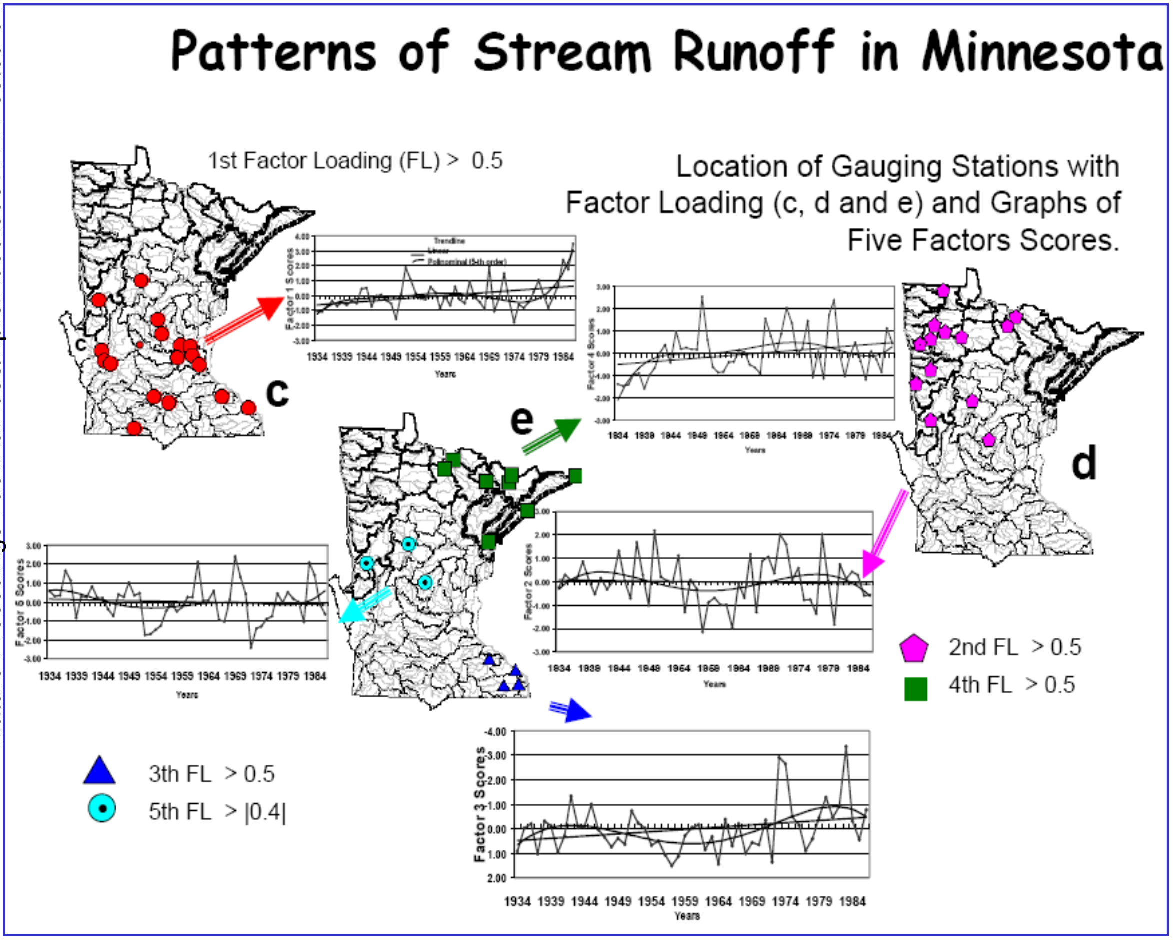
Topic

Research results:

Main patterns of stream flow &

Seasonal distribution stream flow

Results of stream flow pattern analysis 1935-87



НАУЧНЫЙ ЖУРНАЛ
ГЕОГРАФИЯ И ПРИРОДНЫЕ РЕСУРСЫ
№ 1 1999

ГЕОГРАФИЯ ЗА РУБЕЖОМ

УДК 551.48 (776)

Б. А. ШМАГИН, К. А. ДЖОНСТОН, Г. Д. МОЕРС

ИССЛЕДОВАНИЕ ПРОСТРАНСТВЕННО-ВРЕМЕННОЙ ИЗМЕНЧИВОСТИ РЕЧНОГО СТОКА ШТАТА МИННЕСОТА (США) НА ОСНОВЕ ВЕРОЯТНОСТНЫХ МОДЕЛЕЙ

Shmagin, B.A., Johnston, C.A., and H.D. Mooers. 1999. Research of space-time changeability of Minnesota, U.S. river inflow on probability model base (in Russian). Russian Academy of Science. Siberian branch. Geografiia i prirodnye resursy (Geography and natural resources), No. 1, 134-143.

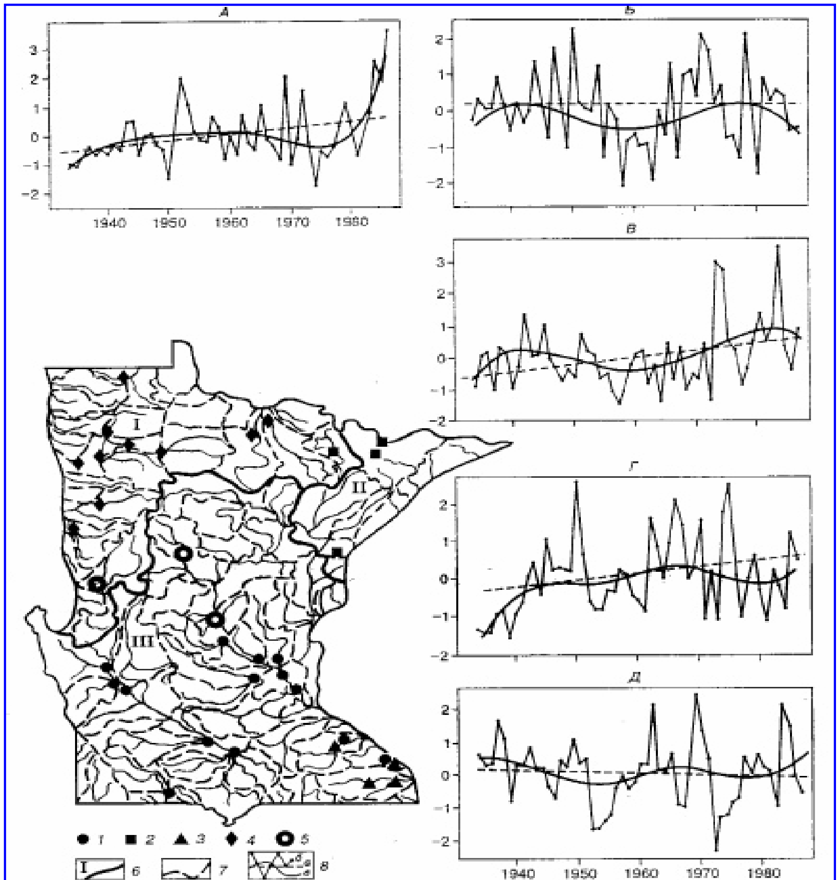


Рис. 1. Пространственно-временная изменчивость речного стока на территории Миннесоты.

1–5 — факторы; границы: *6* — главных бассейнов (I — Ред-Ривер, II — оз. Верхнее, III — р. Миссисипи), *7* — остальных; *8* — графики компонентных кривых факторов (*А–Д*): *а* — линейный тренд, *б* — факторные значения, *в* — полином пятой степени; по оси *X* — период наблюдений 1934—1986 гг., по оси *Y* — факторные значения. Другие усл. обозн. см. в тексте.

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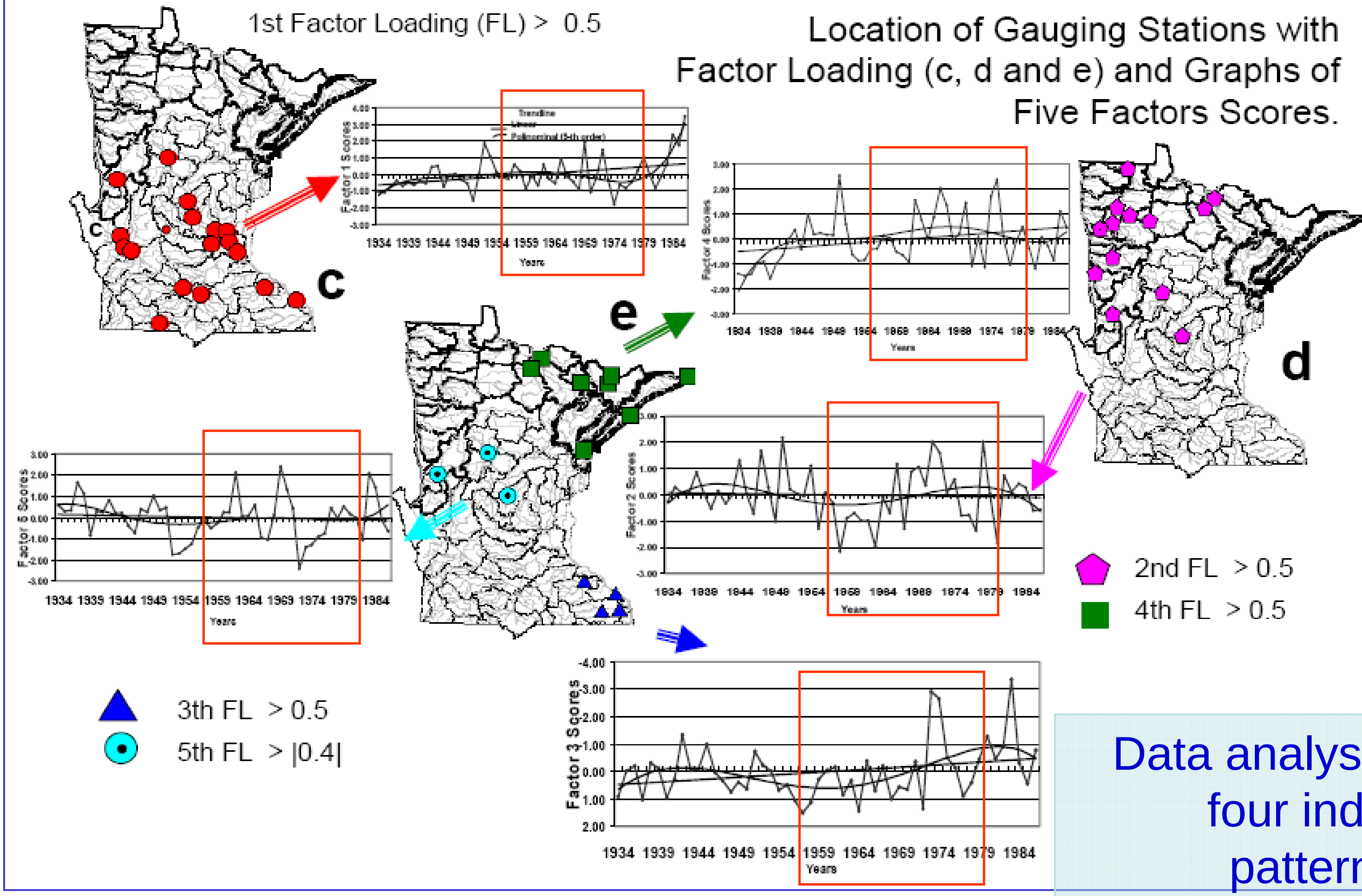
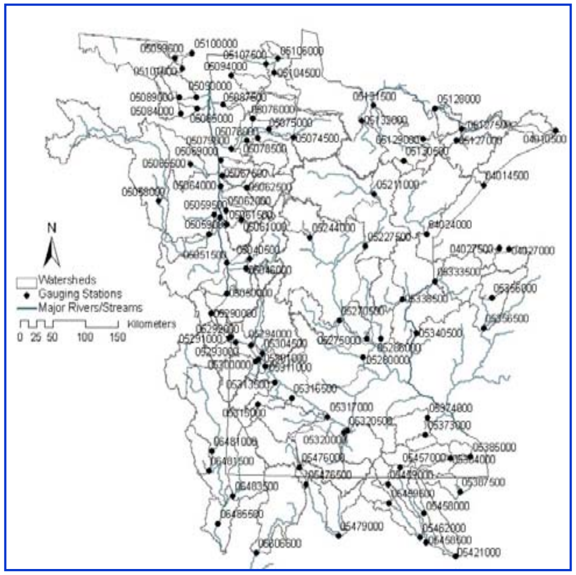
Research was completed 1998 but was not published in full by English language journal

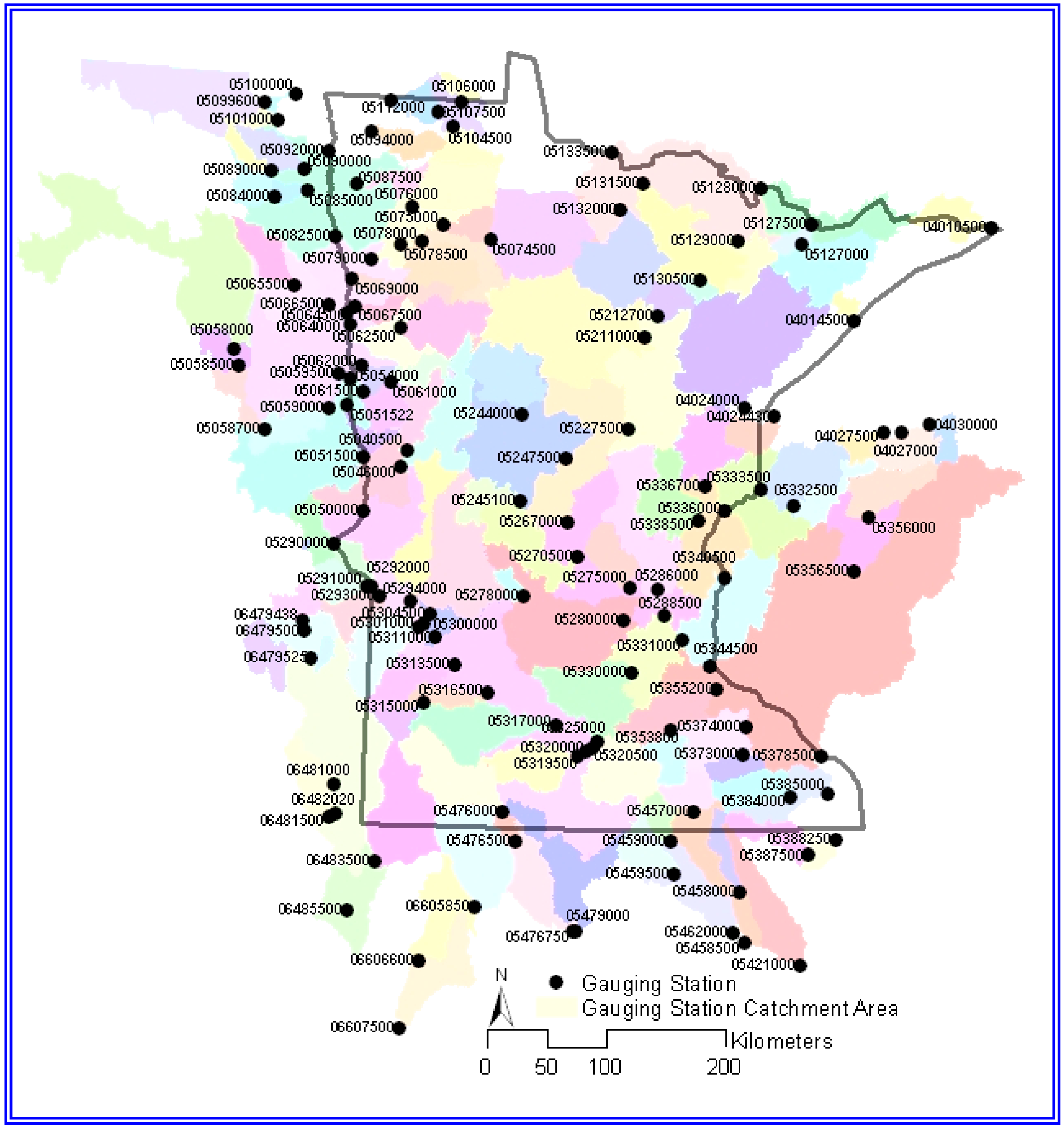


Data analysis reveals four independent patterns for four different regions of MN

System analysis of stream flow pattern forms the basis of data comparison for 1955-79

Stream flow gauges & watersheds for MN



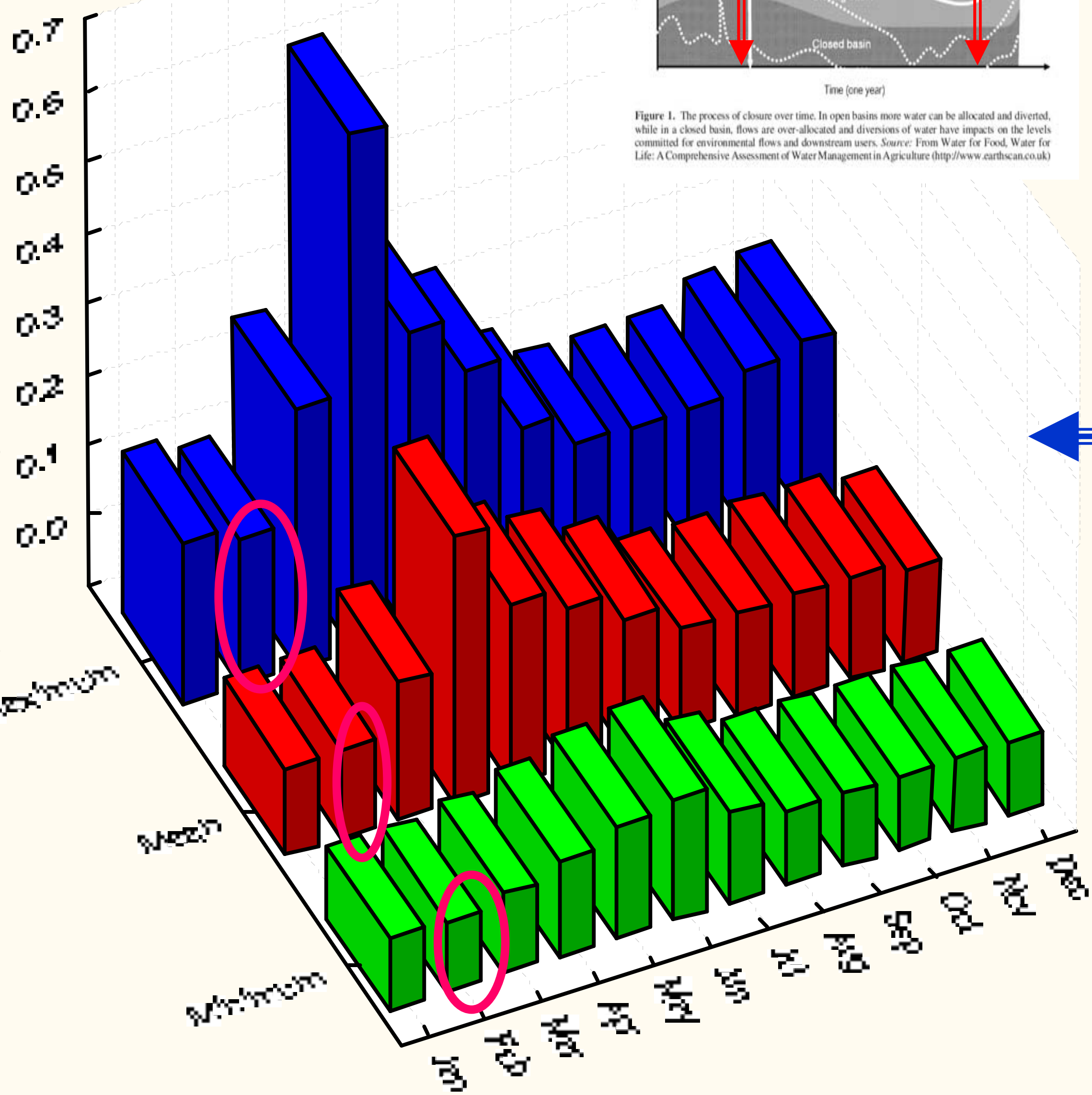


Initial matrix for analysis of seasonal stream flow variability (1955-79):

$Q_{(n*p)}$ or $Q_{(93*14)}$

where are:
n=93 – number of rows or watersheds,
p=14 – number of variables or 12 monthly proportions, February & annual yield

3D Sequential Graph of Monthly Proportions



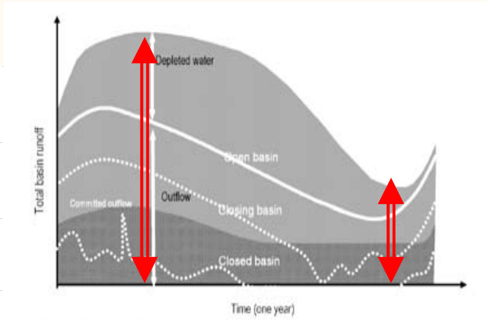
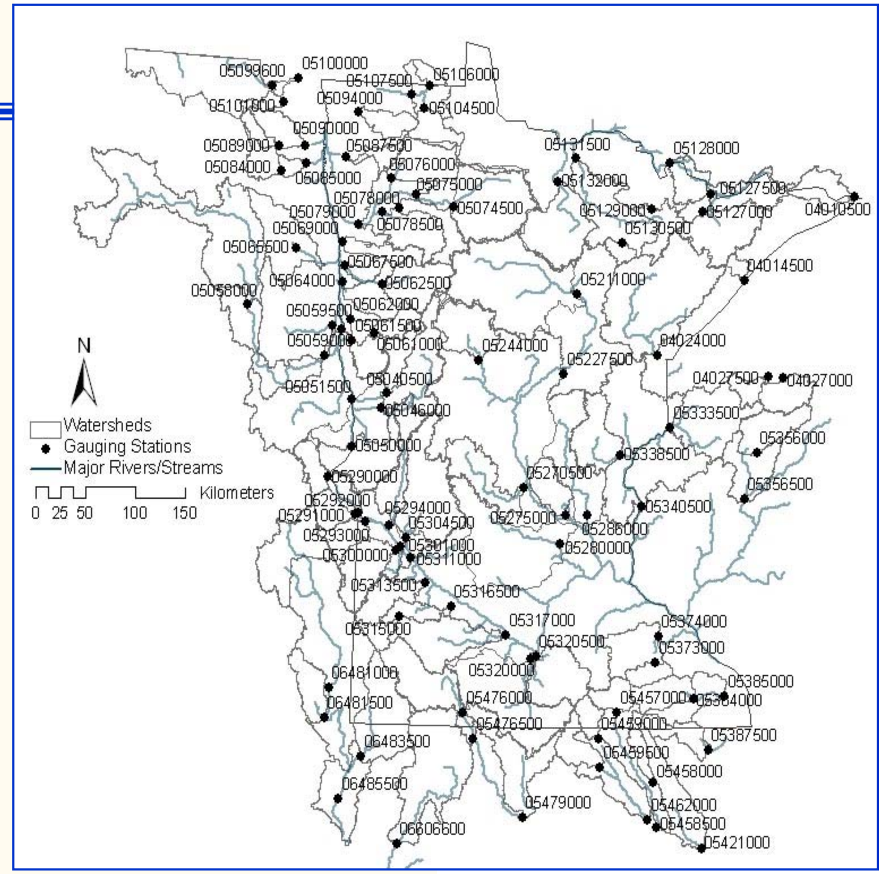
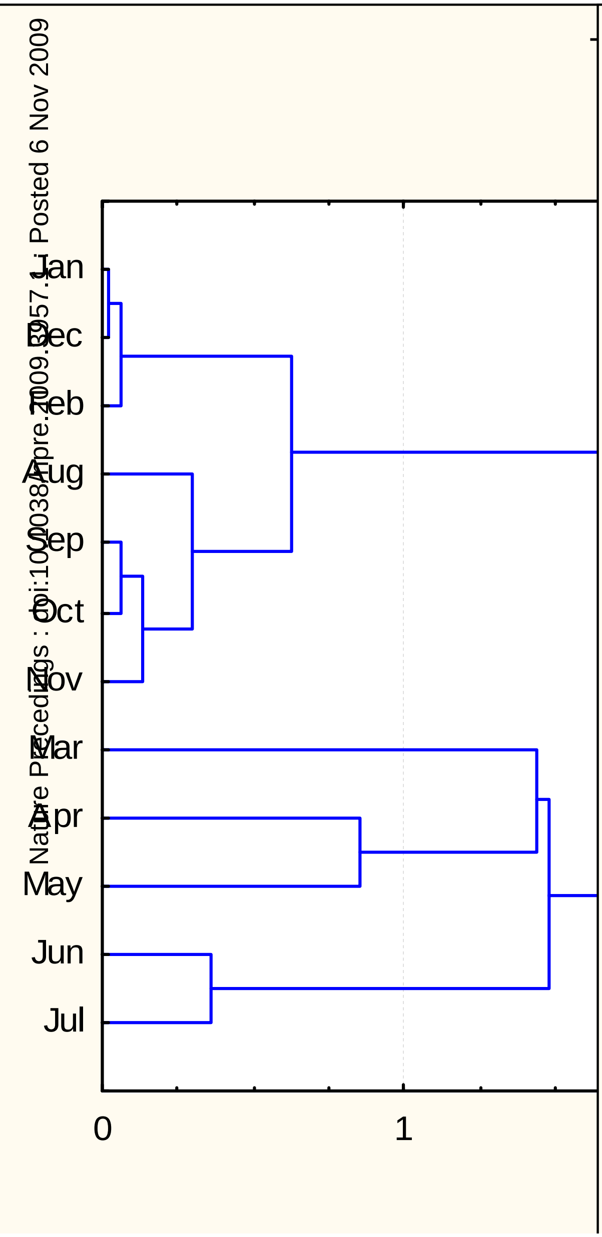


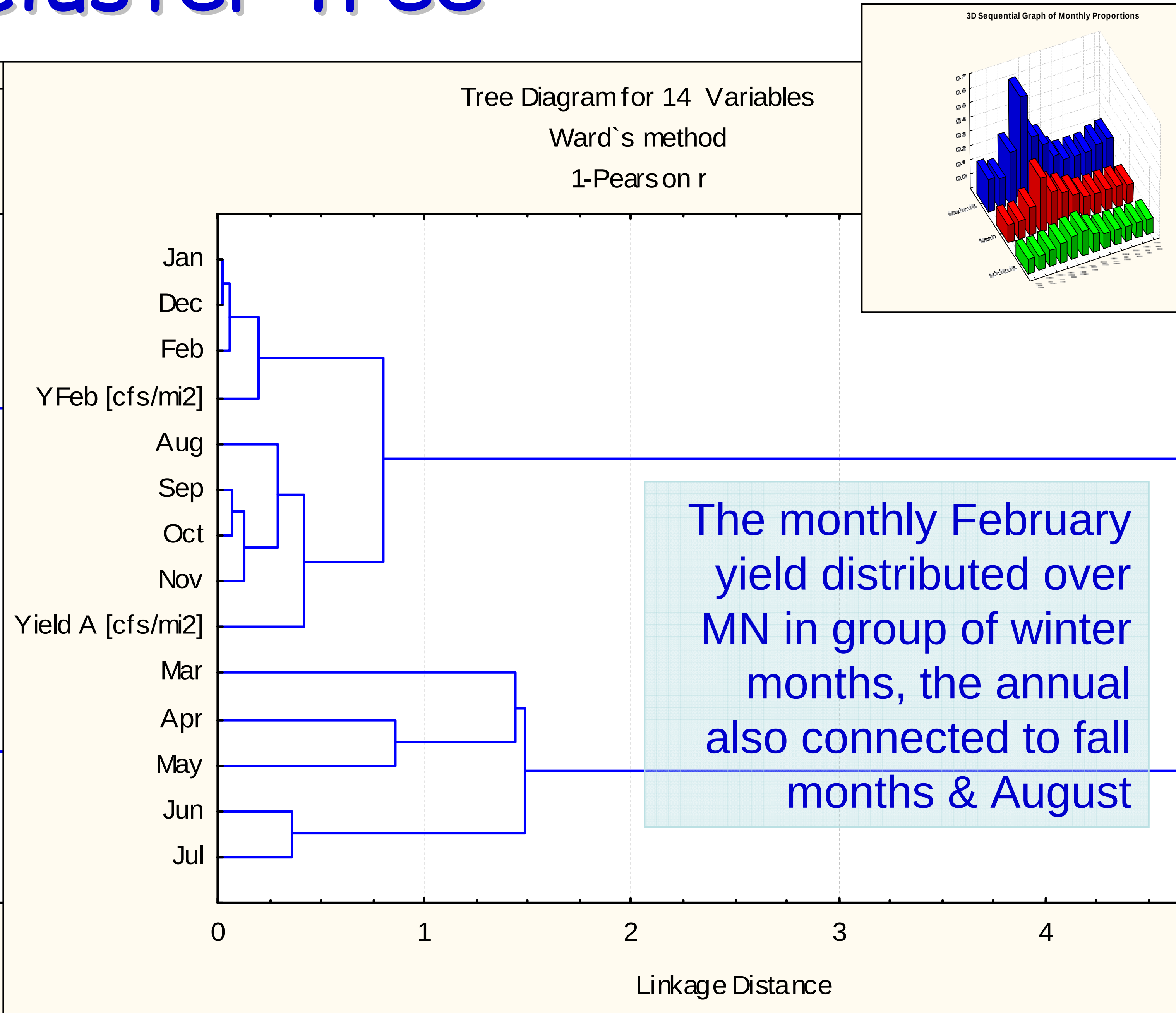
Figure 1. The process of closure over time. In open basins more water can be allocated and diverted, while in a closed basin, flows are over-allocated and diversions of water have impacts on the levels committed for environmental flows and downstream users. *Source:* From Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture (http://www.earthscan.co.uk)

The "hydrograph" of stream flow in MN



The monthly stream runoff for MN as a cluster tree





The monthly February yield distributed over MN in group of winter months, the annual also connected to fall months & August

The monthly runoff in MN as Factor Loading structure

Factor Loadings, Factor 1 vs. Factor 2 vs. Factor 3
Rotation: Varimax normalized
Extraction: Principal components

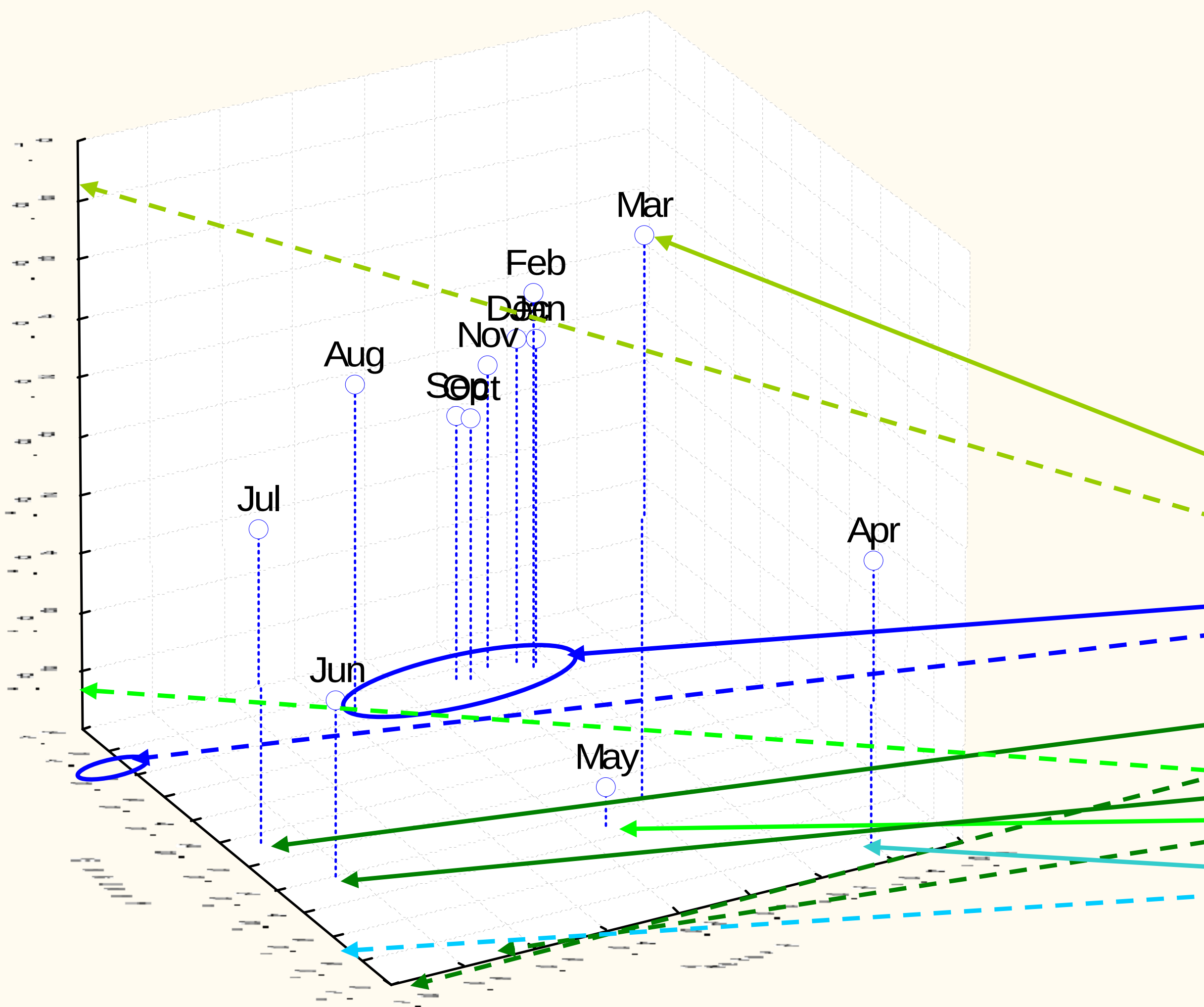
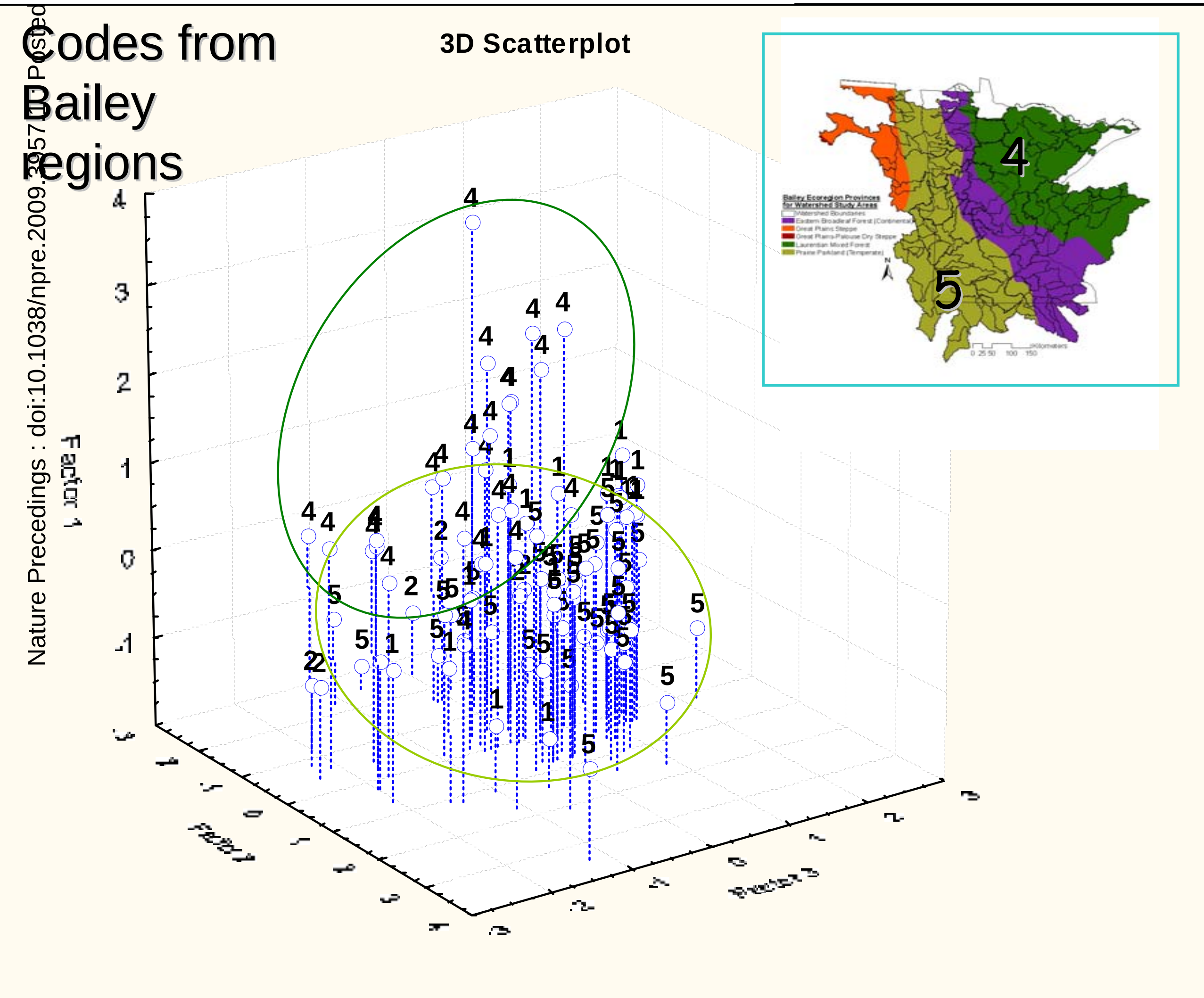
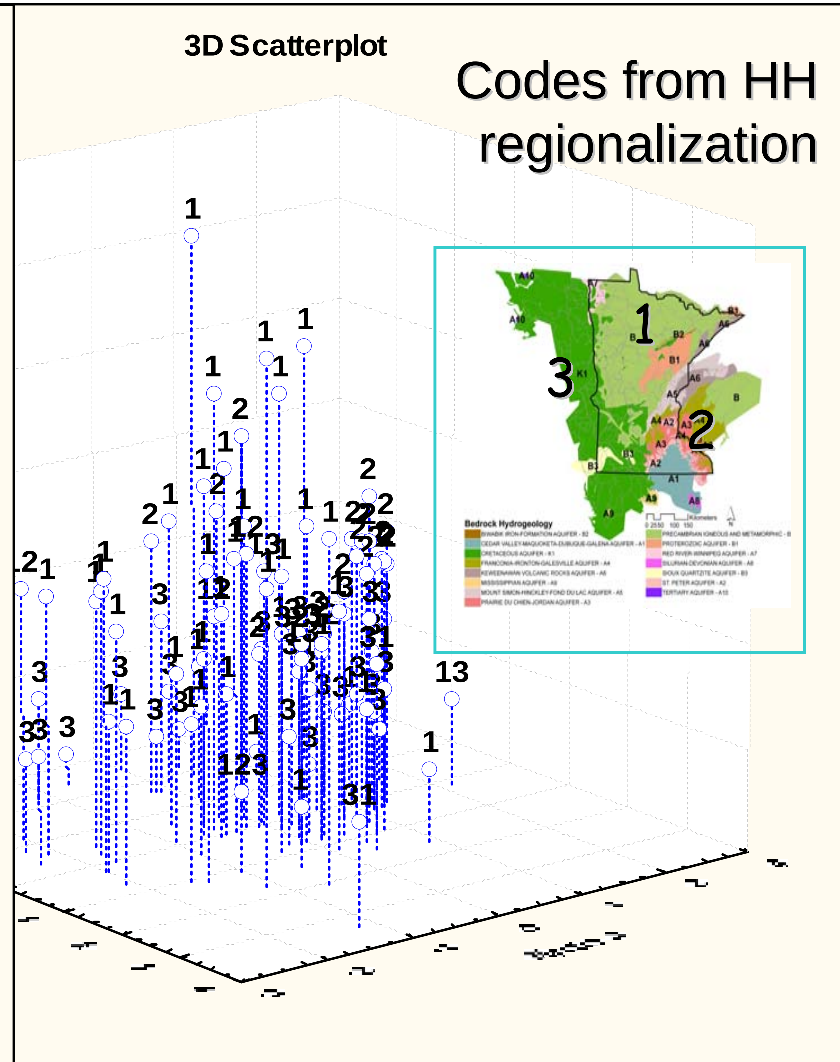


Table of Factor Loading of monthly proportion for 1955-79

	Factor 1	Factor 2	Factor 3
Nov	**0.96**		
Dec	**0.95**		
Sep	**0.92**		
Jan	**0.91**		
Oct	**0.90**		
Feb	**0.88**		0.28
Aug	**0.84**	0.37	
Jul		**0.91**	
Mar			**0.90**
Jun		**0.84**	-0.40
May	0.30		**-0.87**
Apr	**-0.87**	-0.39	
Expl.Var	6.72	1.92	1.87
Prp.Totl	0.56	0.16	0.16

Factor Scores for watersheds in coordinates of stream flow monthly proportions in MN



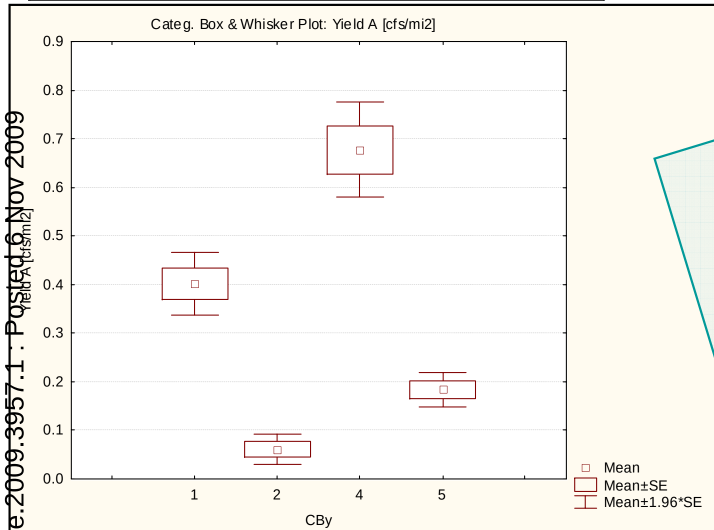


Topic

Map of WR as
result of statistical analysis of landscape
originated properties (layers) &
role of geology & hydrogeology in
controlling maps' boundaries

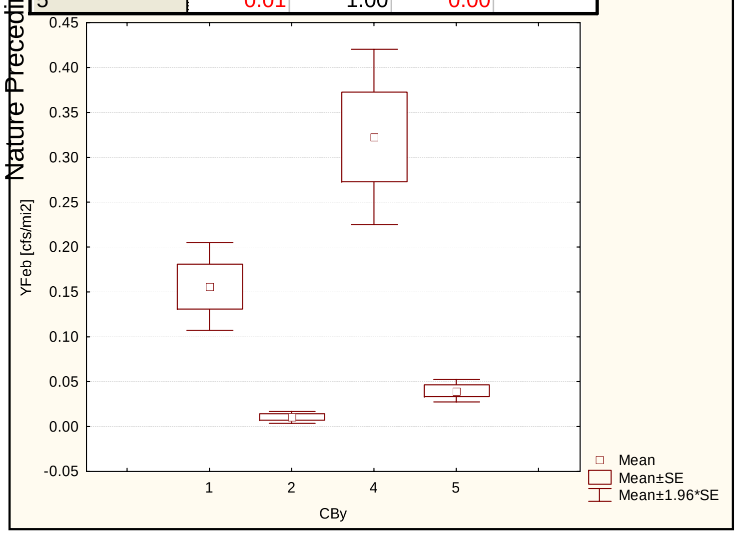
Multiple Comparisons p values (2-tailed); Yield A [cfs/mi2]
Independent (grouping) variable: CBy
Kruskal-Wallis test: H (3, N= 90) =61.71899 p =.0000

Depend.: Yield A [cfs/mi2]	1 R:58.000	2 R:7.8571	4 R:73.875	5 R:29.829
1		0.00	0.31	0.00
2	0.00		0.00	0.24
4	0.31	0.00		0.00
5	0.00	0.24	0.00	

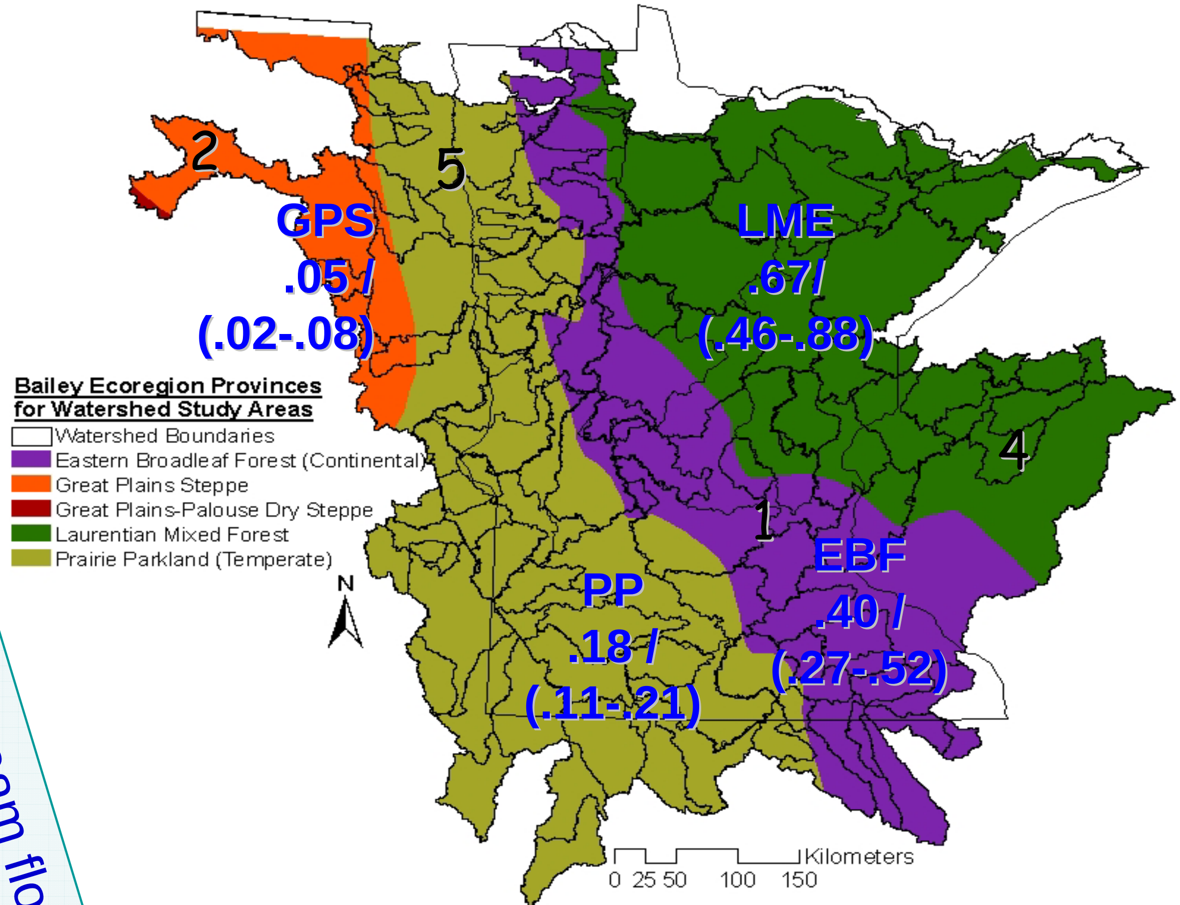


Multiple Comparisons p values (2-tailed); YFeb [cfs/mi2]
Independent (grouping) variable: CBy
Kruskal-Wallis test: H (3, N= 90) =48.58212 p =.0000

Depend.: YFeb [cfs/mi2]	1 R:54.889	2 R:16.143	4 R:71.958	5 R:30.902
1		0.01	0.22	0.01
2	0.01		0.00	1.00
4	0.22	0.00		0.00
5	0.01	1.00	0.00	



The yield of stream flow is different for units of ecological regionalization

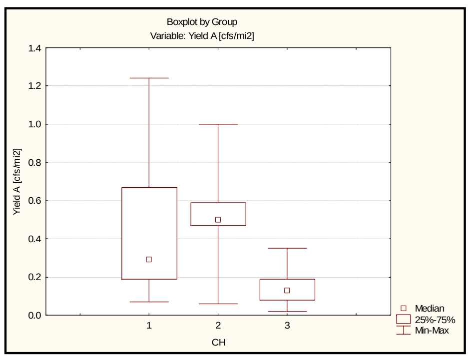


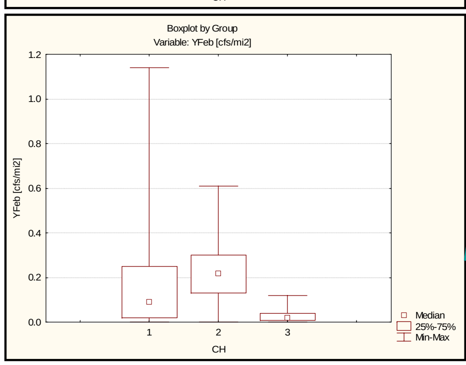
Mean Annual & Feb Yield (1955-1979) for Eco Regions

Numbers on map show:
Black – codes for regionalization.
Blue - average annual yield [cfs/mi^2]/
(quartile lower- quartile upper)

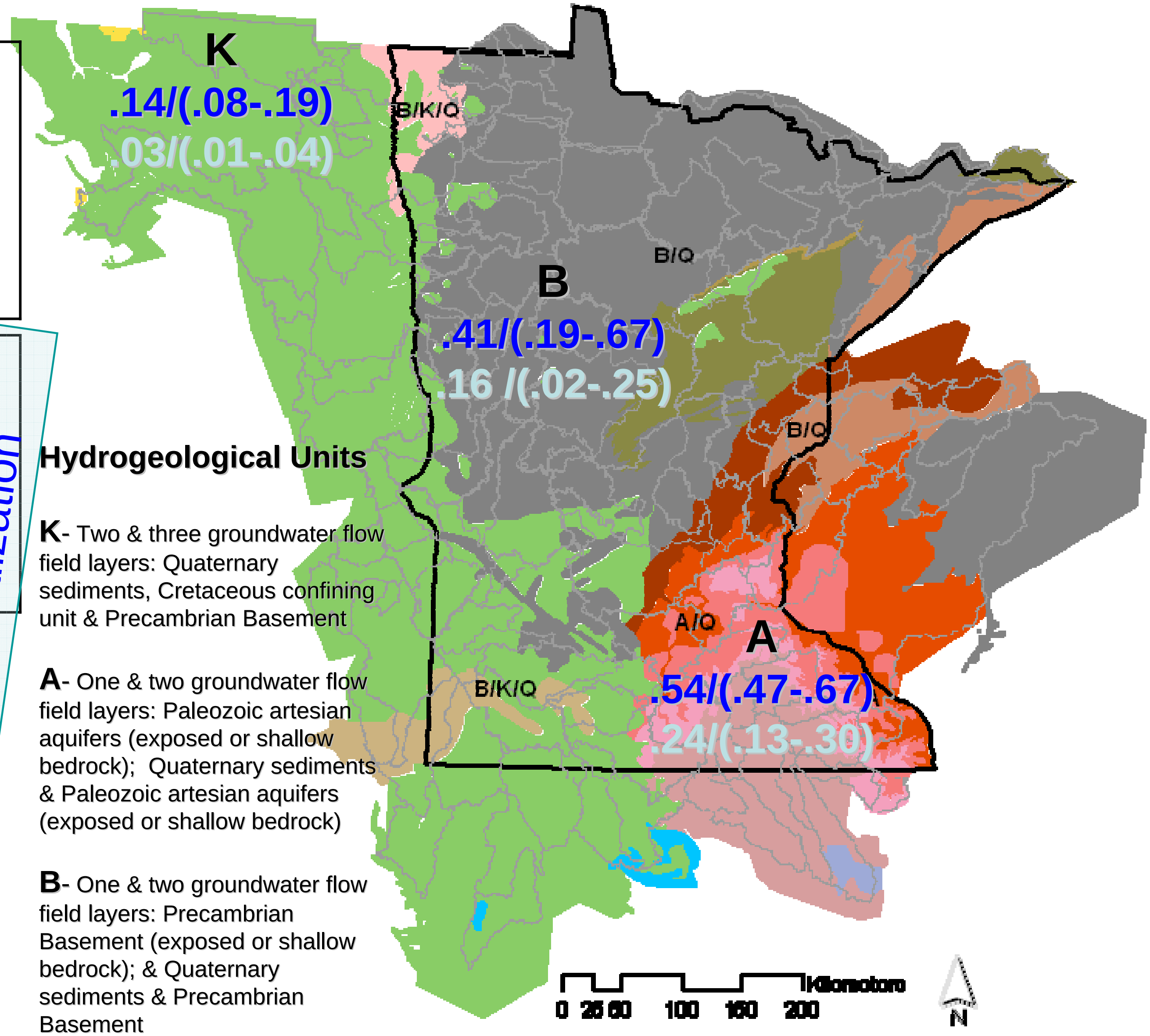
Kruskal-Wallis ANOVA by Ranks;
Yield A [cfs/mi2]
Independent (grouping) variable:
Codes HH
Kruskal-Wallis test:
H (2, N= 93) =38.44 **p =.00**

Kruskal-Wallis ANOVA by Ranks;
Y Feb [cfs/mi2]
Independent (grouping) variable:
Codes HH
Kruskal-Wallis test:
H (2, N= 93) =29.65 **p =.00**





The yield of stream flow is different for units of bedrock regionalization



Hydrogeological Units

K- Two & three groundwater flow field layers: Quaternary sediments, Cretaceous confining unit & Precambrian Basement

A- One & two groundwater flow field layers: Paleozoic artesian aquifers (exposed or shallow bedrock); Quaternary sediments & Paleozoic artesian aquifers (exposed or shallow bedrock)

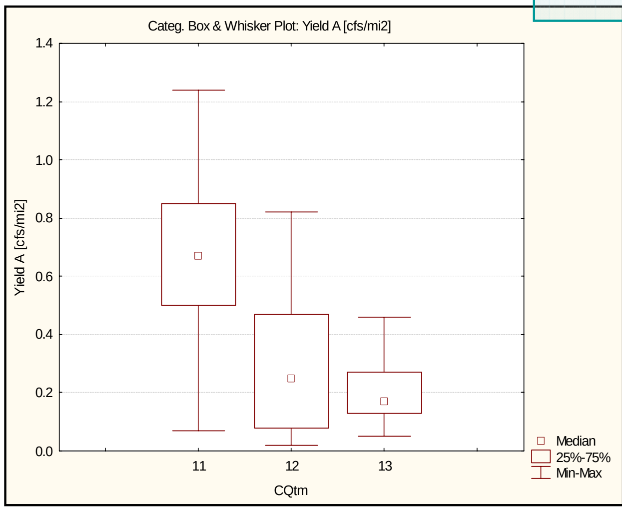
B- One & two groundwater flow field layers: Precambrian Basement (exposed or shallow bedrock); & Quaternary sediments & Precambrian Basement

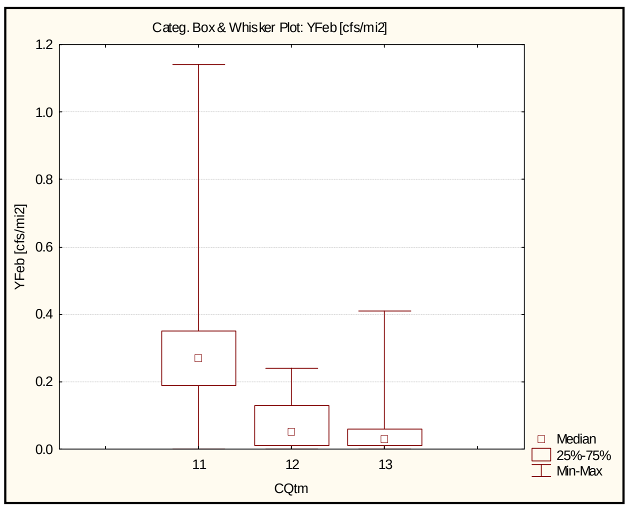
Mean Annual & February Yield (1955-1979) for bedrocks

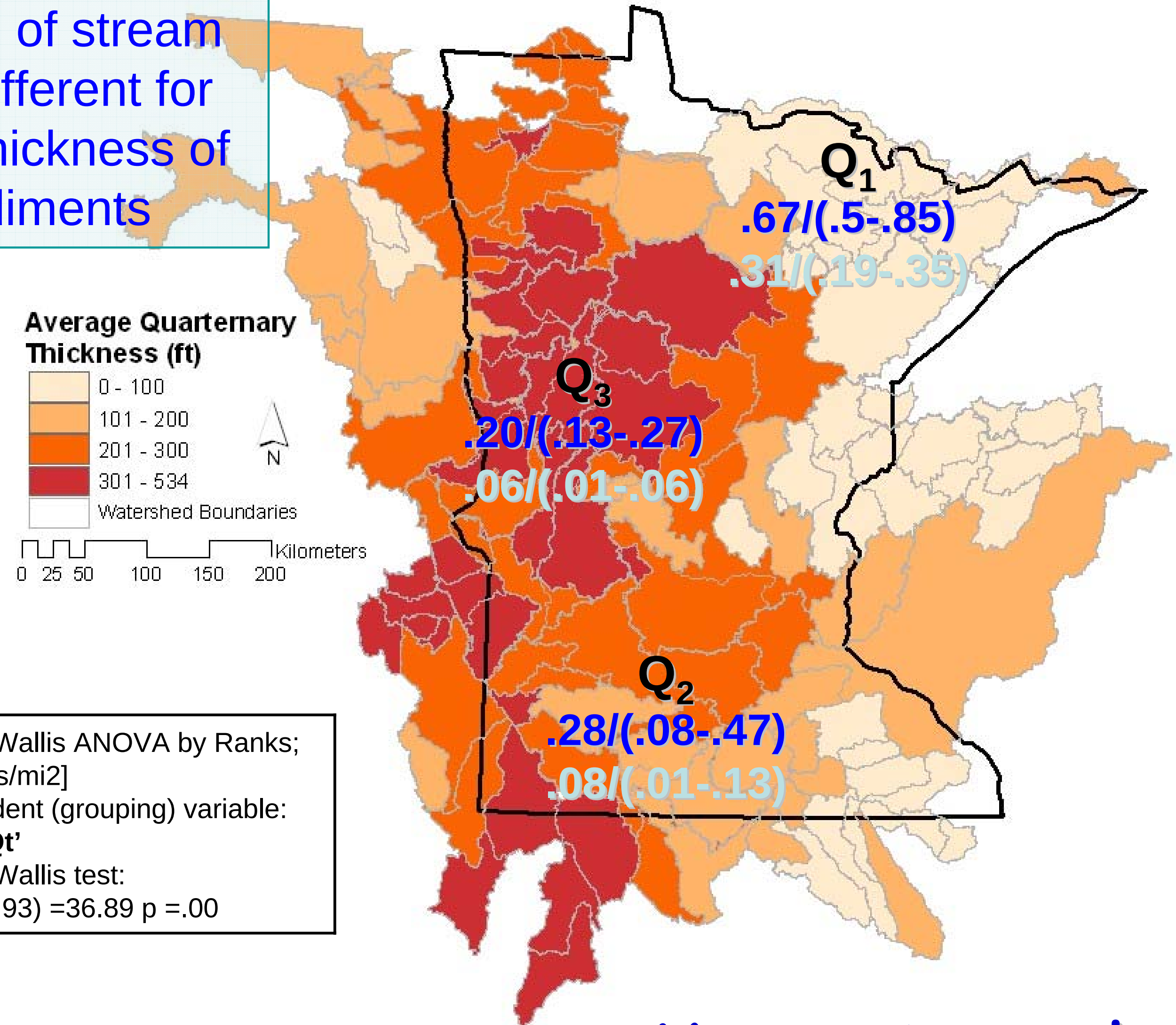
Numbers show: mean yield / (quartile lower- quartile upper) [cfs/mi2]

Kruskal-Wallis ANOVA by Ranks;
Yield A [cfs/mi2]
Independent (grouping) variable:
Codes Qt
Kruskal-Wallis test:
H (2, N= 93) =43.71 p =.00

The yield of stream flow is different for units of thickness of Q sediments







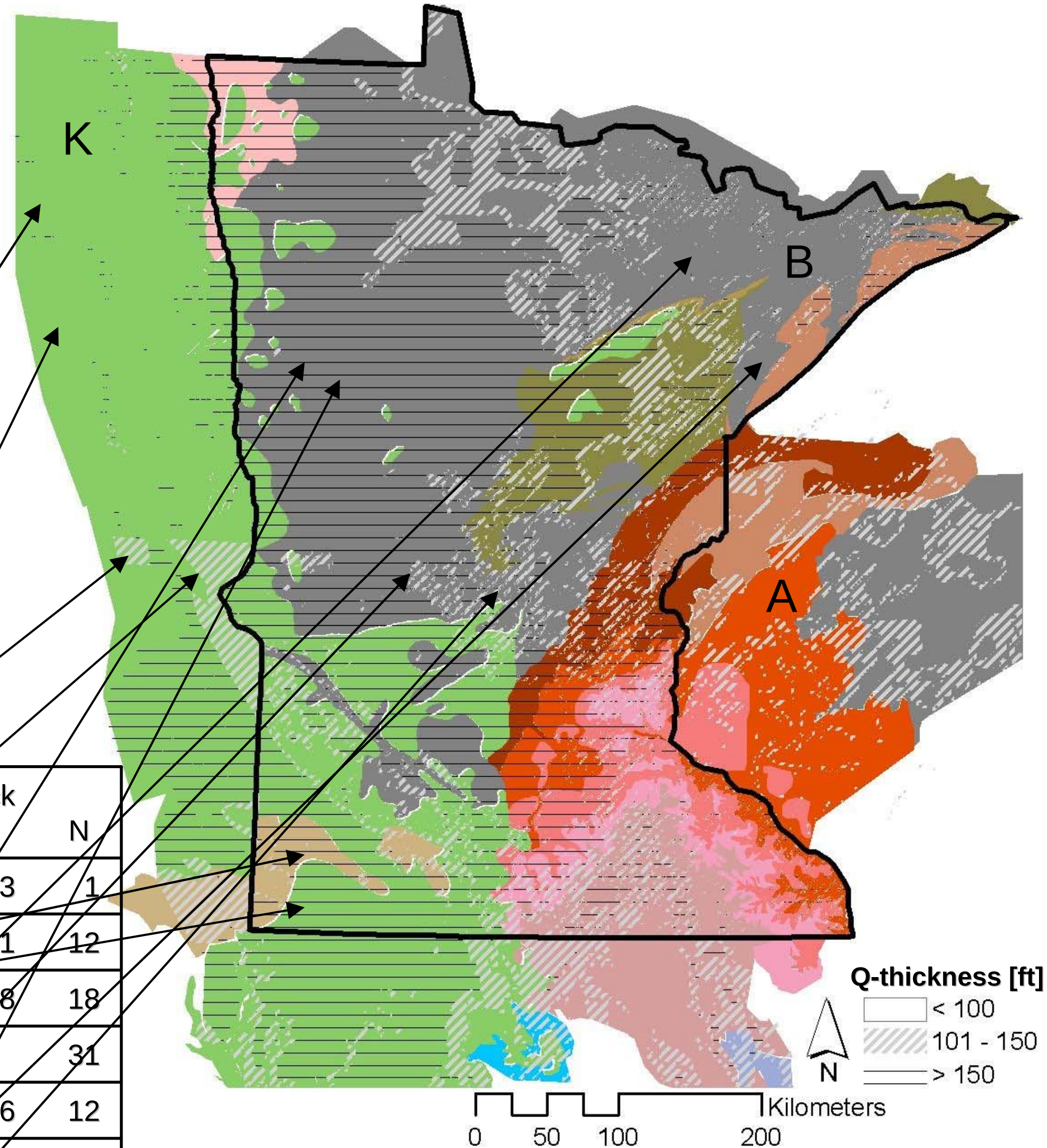
Kruskal-Wallis ANOVA by Ranks;
YFeb [cfs/mi2]
Independent (grouping) variable:
Codes Qt'
Kruskal-Wallis test:
H (2, N= 93) =36.89 p =.00

Mean Annual & Monthly February Yield (1955-1979) for Q sediments thickness [ft]

Q_1- thickness: 0-100 [ft], Q_2: 100-150 [ft], Q_3: > 150 [ft]
Numbers on map show: mean yield / (quartile lower- quartile upper) [cfs/mi2]

Mean Annual & February Yield (1955-1979) for units of HH regionalization & Q-deposits thickness

DA [km2]	Tot. Den	Mean Altit [ft]	Slope [%]	Yield Ann [cfs/mi2]	Yield Feb [cfs/mi2]	HH	Q-thick [ft]	N
3199.4	0.59	1226.3	4.2	0.07	0.00	K	85.3	1
5622.1	0.50	1384.2	6.6	0.13	0.02	K	127.1	12
5424.8	0.81	1414.0	8.4	0.15	0.03	K	289.8	18
								31
3492.9	0.73	1195.3	14.9	0.63	0.31	A	55.6	12
1465.3	0.65	1214.7	6.3	0.51	0.17	A	125.1	4
7721.6	0.49	1117.5	5.4	0.19	0.03	A	202.1	3
								19
3104.6	0.52	1424.4	11.7	0.75	0.34	B	62.2	13
3028.2	0.46	1336.7	11.2	0.52	0.15	B	138.3	4
3348.3	0.49	1235.5	6.4	0.23	0.08	B	321.3	26
								43



The distribution of WR (↑) in MN is controlled by geological conditions & the structure of landscape

Map of WR, units & boundaries

- Groups of watersheds recognized by mutual landscape properties with statistically proven influence on hydrologic characteristics provide the basis for regionalization & boundary location
- The units on a map reflect regionalization with average hydrologic characteristics with common properties & range in yield
- The values of characteristics on the map reflect the interval of observation (e.g. 1955-1979) & must be placed in long time perspective

Topics

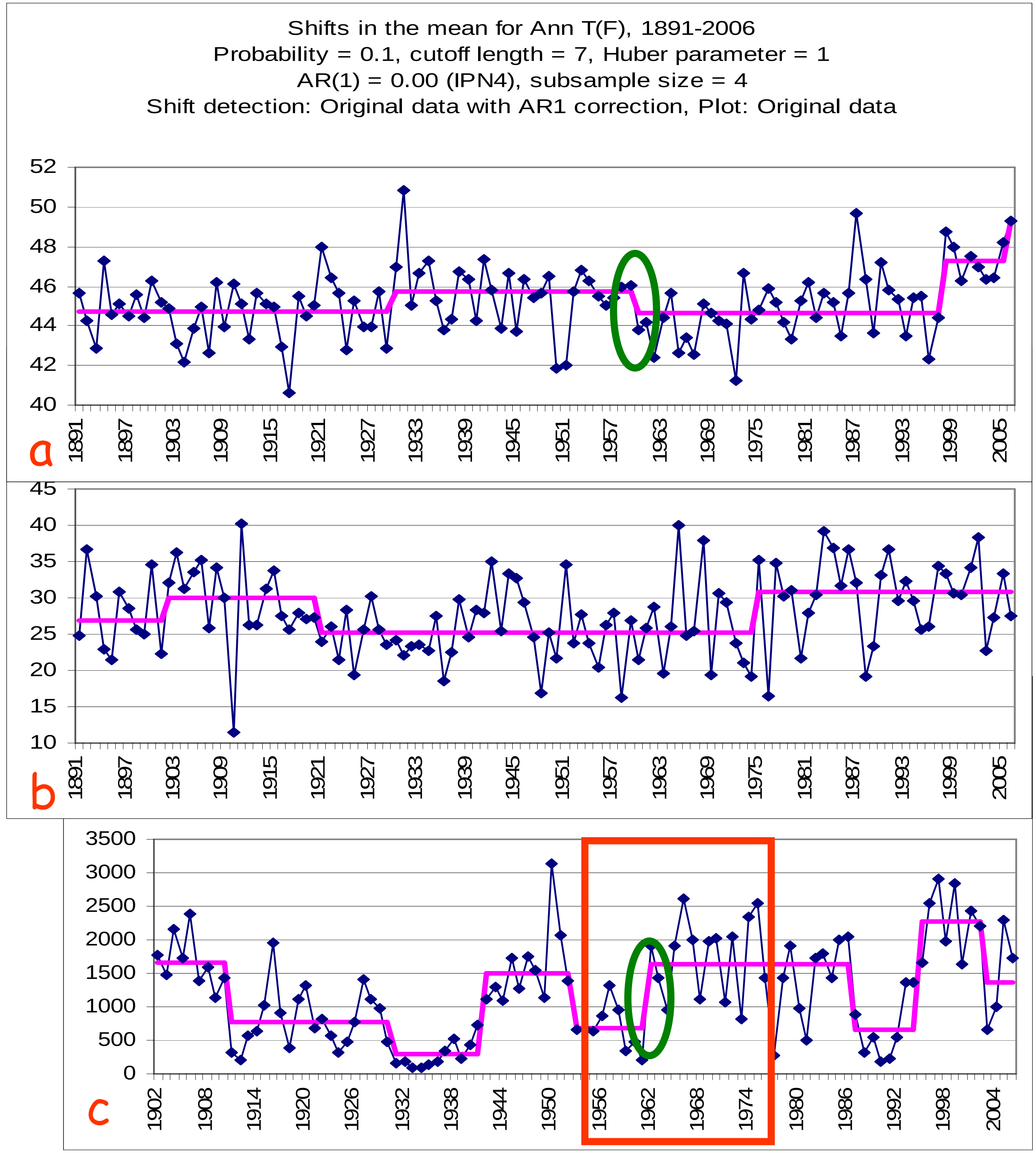
Map of WR & analysis of regime –
the way to incorporate
climate influence on WR
monitoring & management

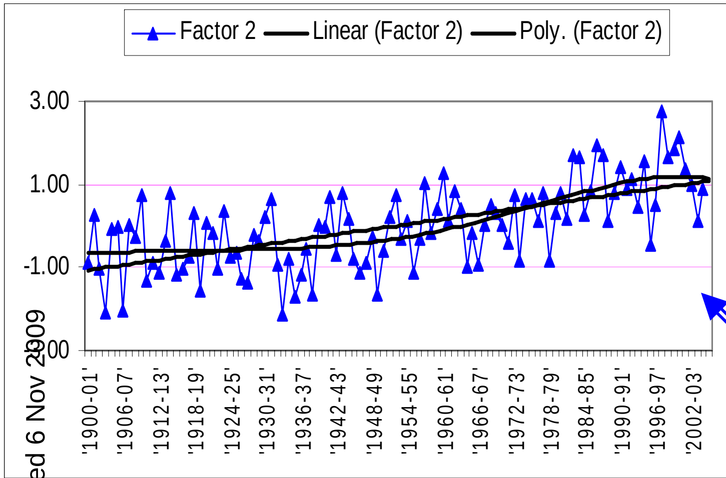
To study climate characteristics & place the map in time perspective for management of WR

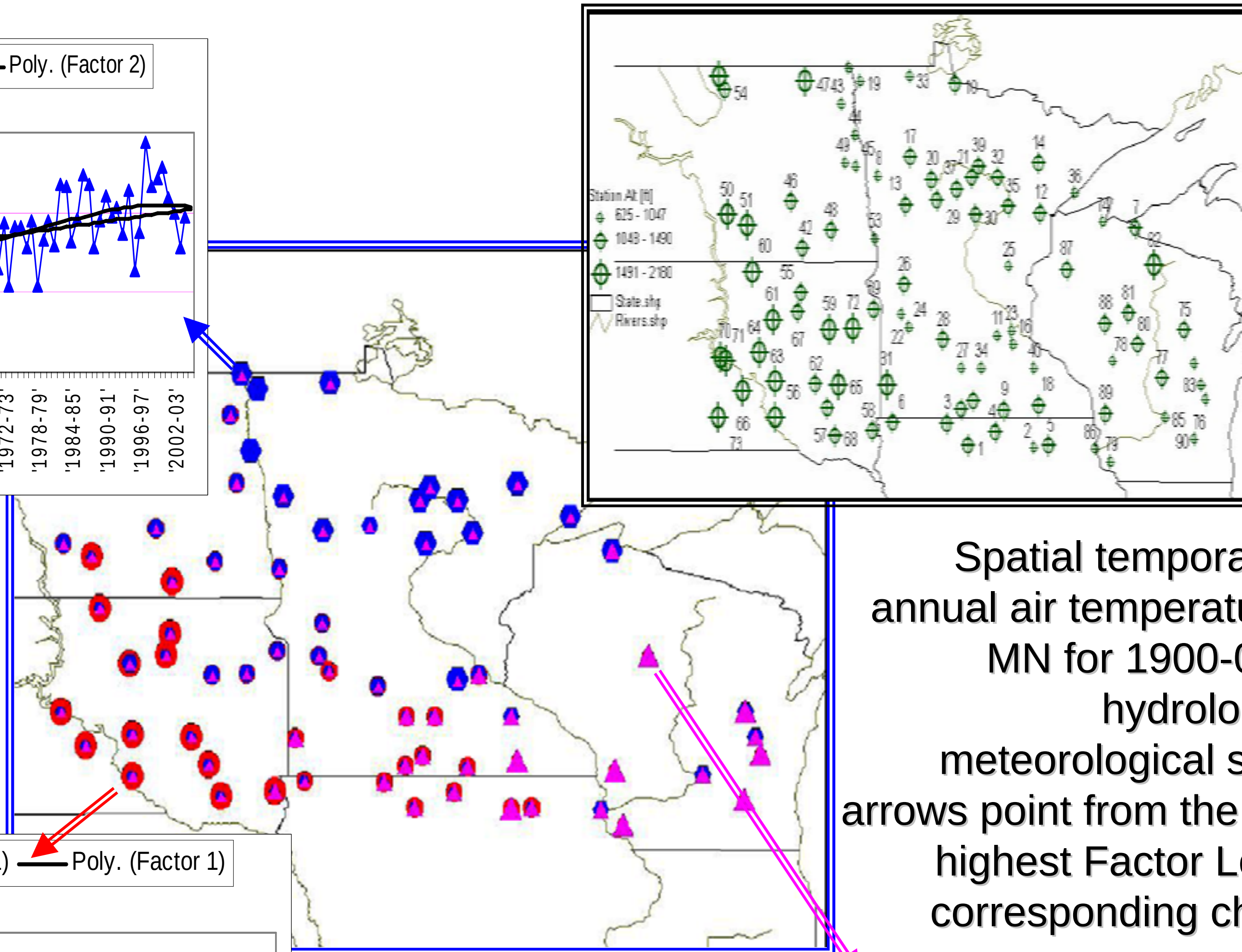
Air temperature (Minneapolis) - a

Precipitation (Minneapolis) - b

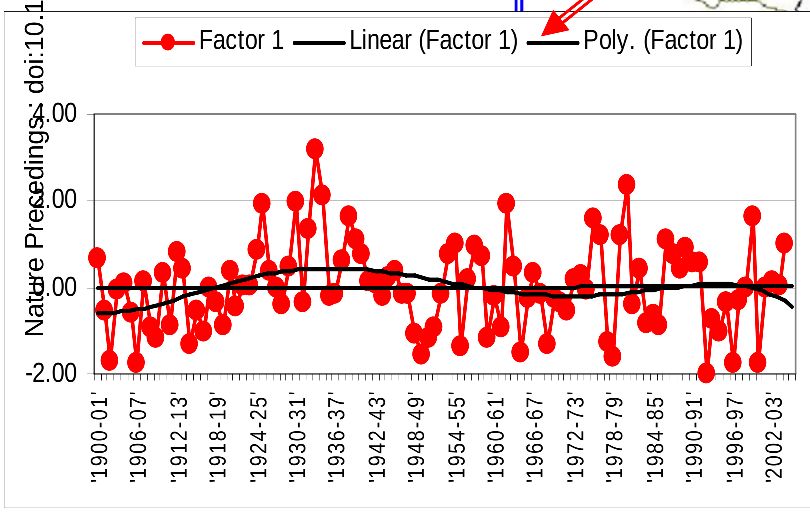
Stream runoff (Red Lake River) - c

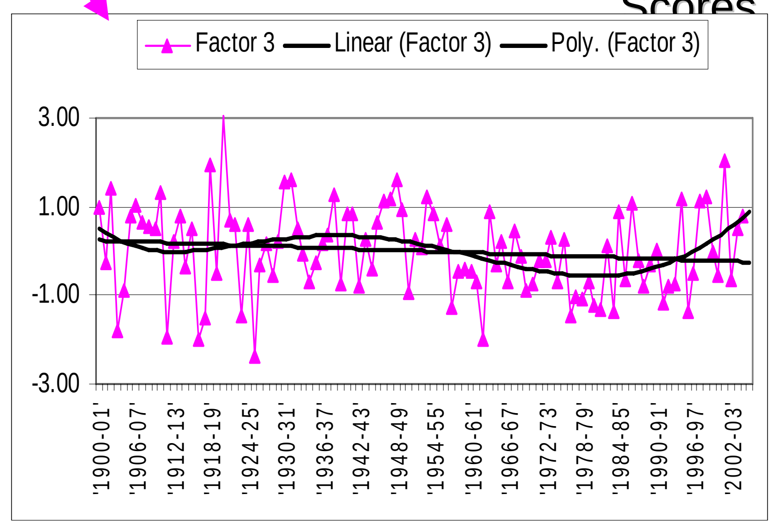






Spatial temporal structure of annual air temperature regime in MN for 1900-01 – 2004-05 hydrologic years (70 meteorological stations). The arrows point from the stations with highest Factor Loading to the corresponding chart of Factor Scores

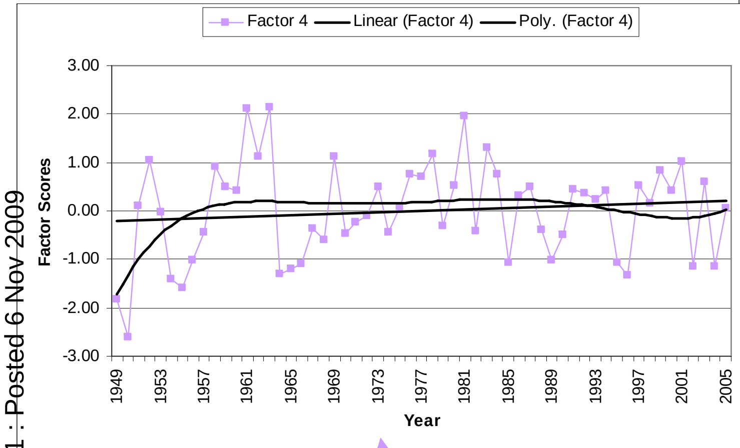


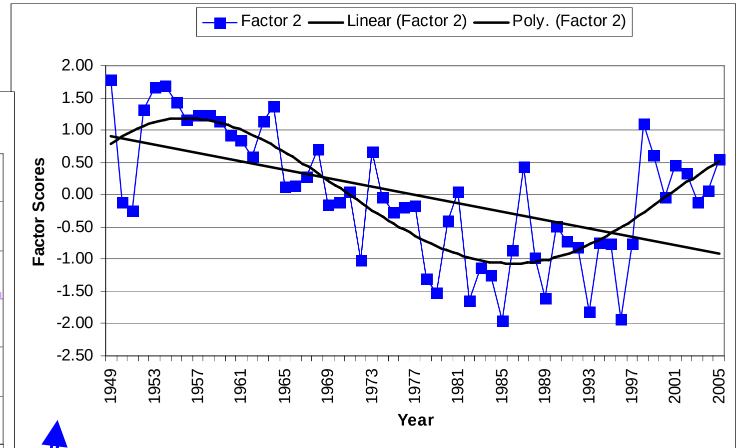


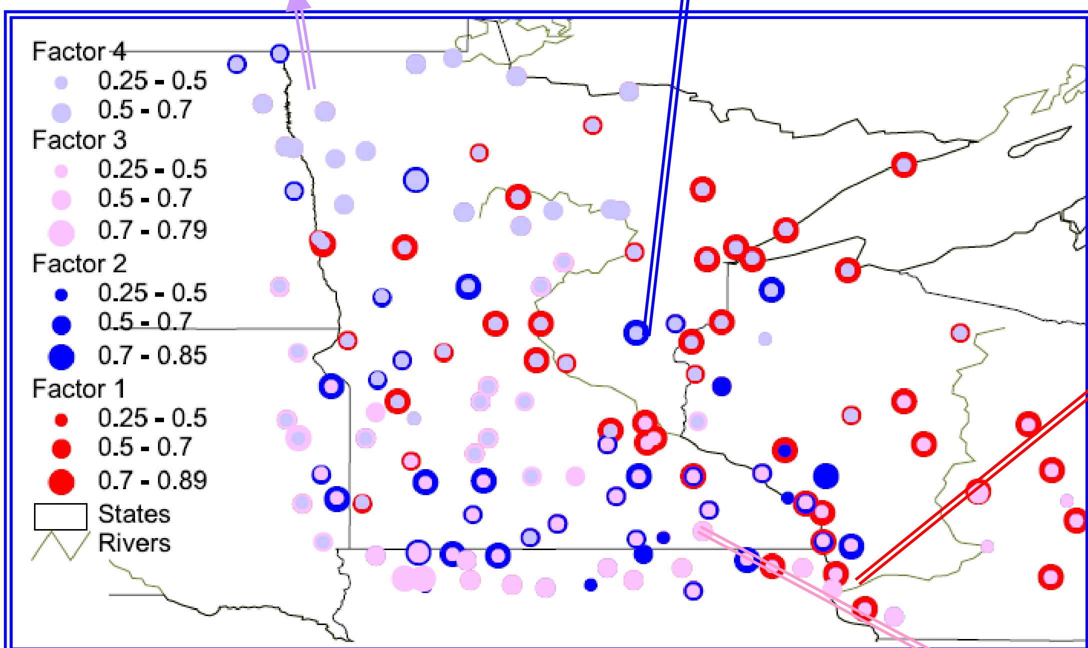
Air temperature

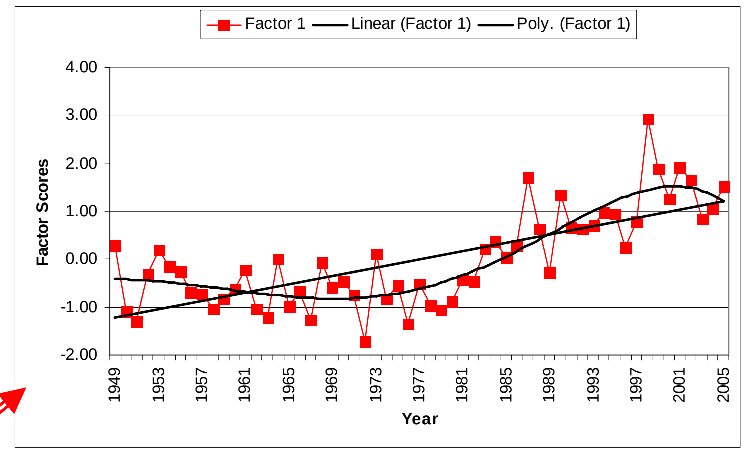
Spatial temporal structure of annual air temperature regime in MN for 1949 – 2005 (138 meteo stations).

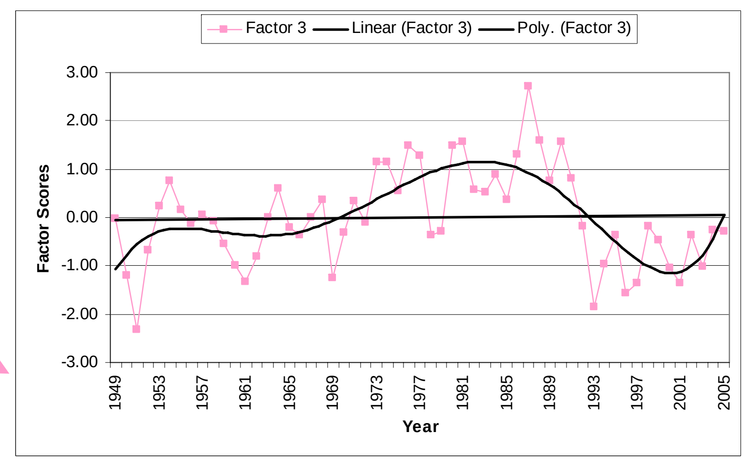
The arrows point from the stations with highest Factor Loading to the corresponding chart of Factor Scores





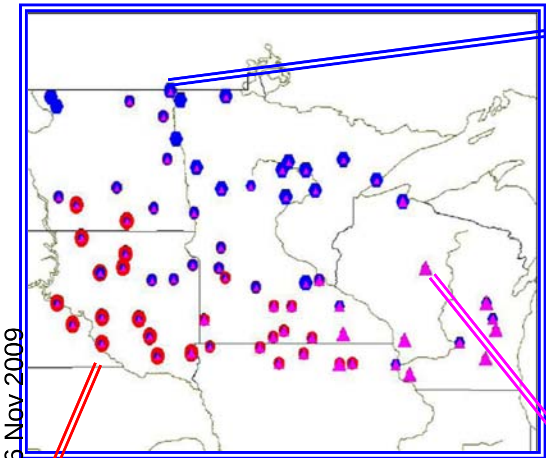


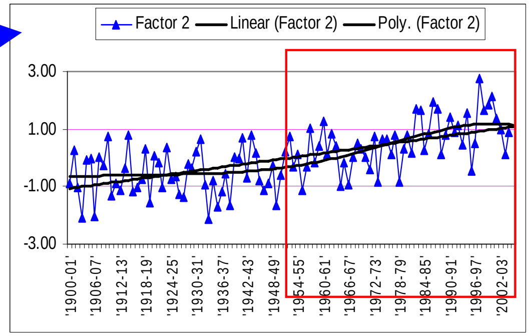


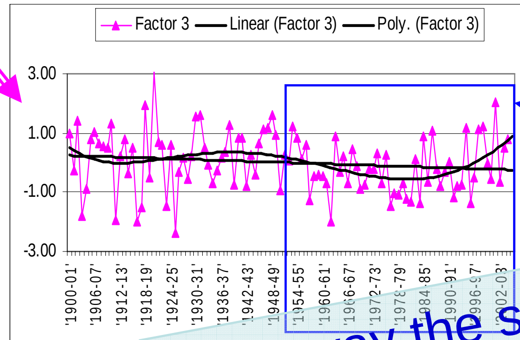


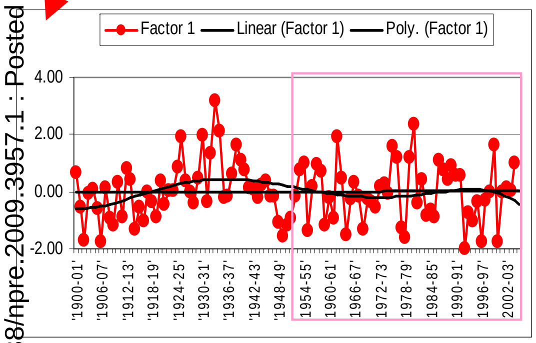
Air temperature

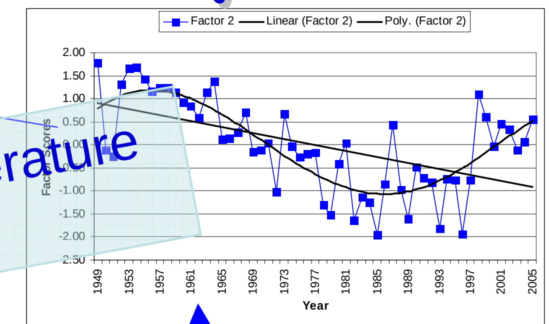
Air temperature for periods of 105 & 57 years



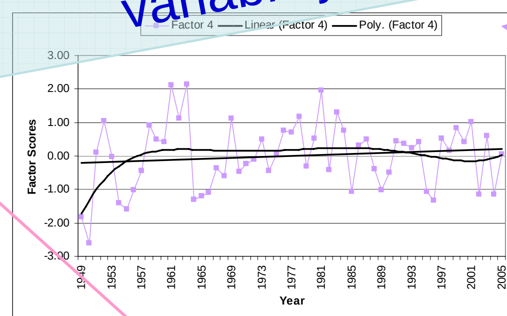


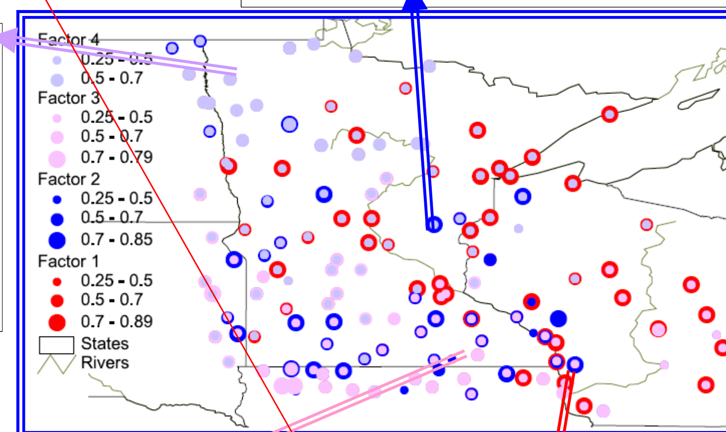




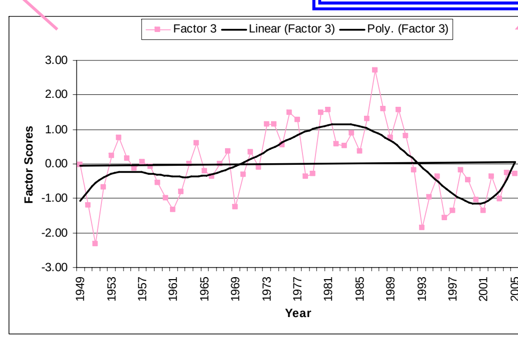


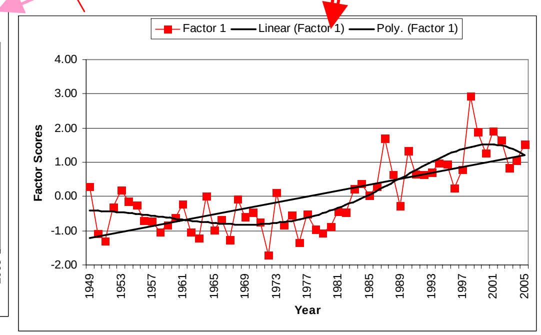
This way the structure of air temperature variability may presented



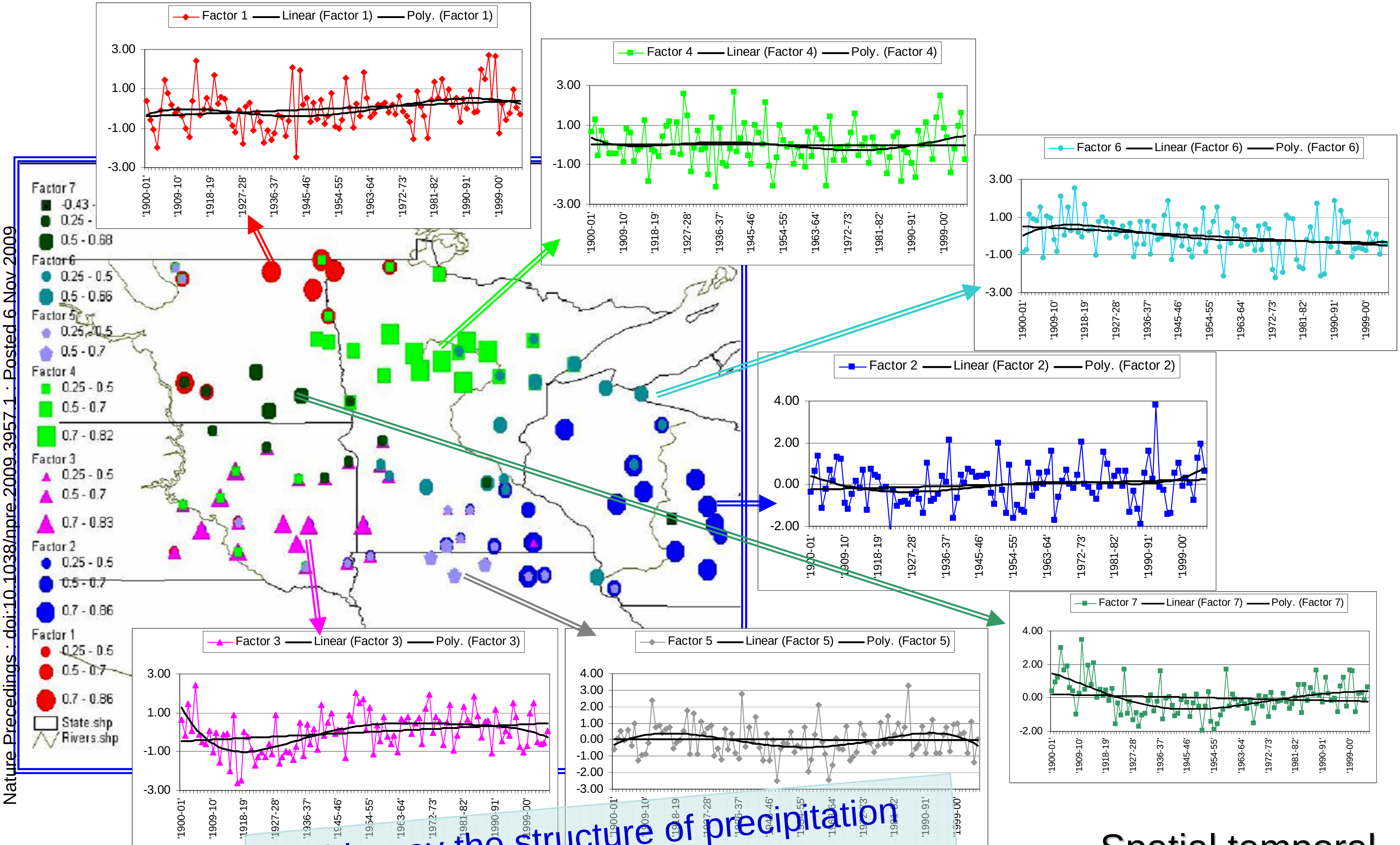


Spatial temporal structure of annual air temperature regime in MN
* for 70 meteo stations & 1900-01 – 2004-05 hydrologic years (upper), &
* for 138 meteo stations & 1949 – 2005 (right).





The arrows point from the stations with highest Factor Loading to the corresponding chart of Factor Scores.
Rectangles show some similarity in curves.



This way the structure of precipitation variability may presented

Spatial temporal structure of annual precipitation regime in MN for 1930-31 – 1984-85 hydrologic years (87 meteo stations)

Precipitation

WR map in 2009 year of Science

editorial

Big, old and complicated

Earth scientists learn to approach scientific questions from a unique perspective — one that Charles Darwin shared.

All geoscientists have an interest in some aspect of the Earth. But little else unites ... o canonical ... h scientists ... other subject ... nding a physics ... in physics,

with an interest in pa... mathematicians turne... and chemists who de... atmospheric chemistr... all consider themselve... Charles Darwin — w... attention in this doub...

THE YEAR OF DARWIN

This essay is the 10th in a monthly series. For more on evolutionary topics online, see the Origins blog at **blogs.sciencemag.org/origins**. For more on ecological structure, listen to a podcast by author Erik Stokstad at **www.sciencemag.org/multimedia/podcast**.

ORIGINS

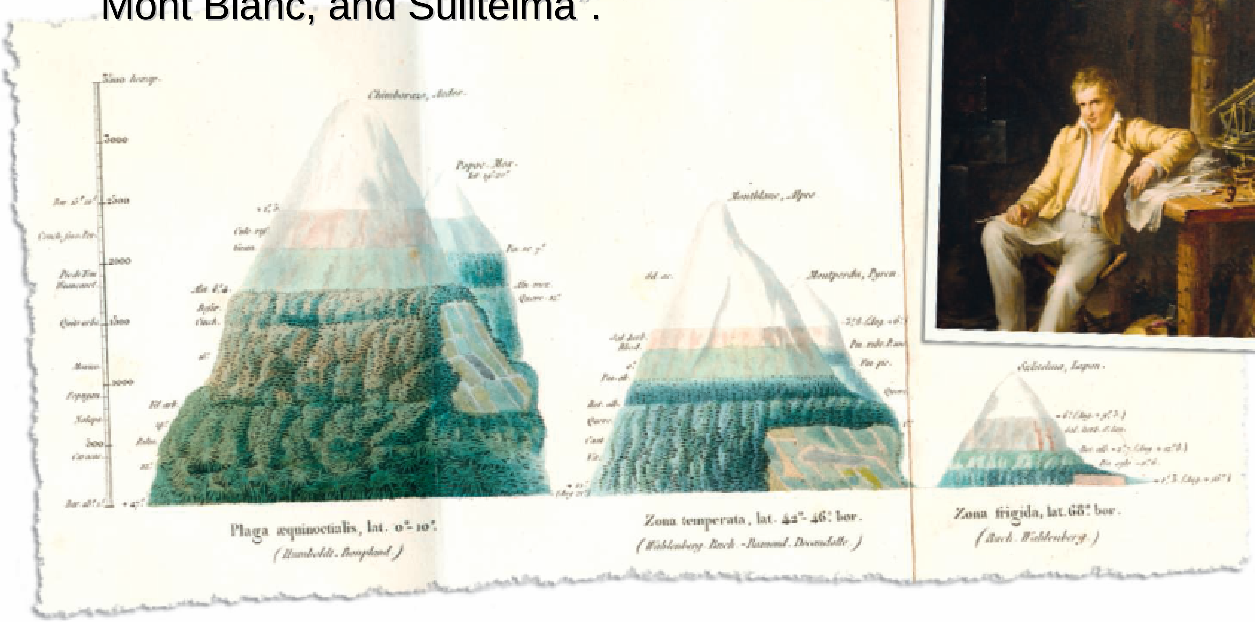
On the Origin of
Ecological Structure

to place, wet tropical forests still exist as recognizable entities on four continents. A combination of physical and biological forces organizes species into these predictable communities.

Following Humboldt's lead, scientists in the 19th century assembled evidence that the composition of communities depends on

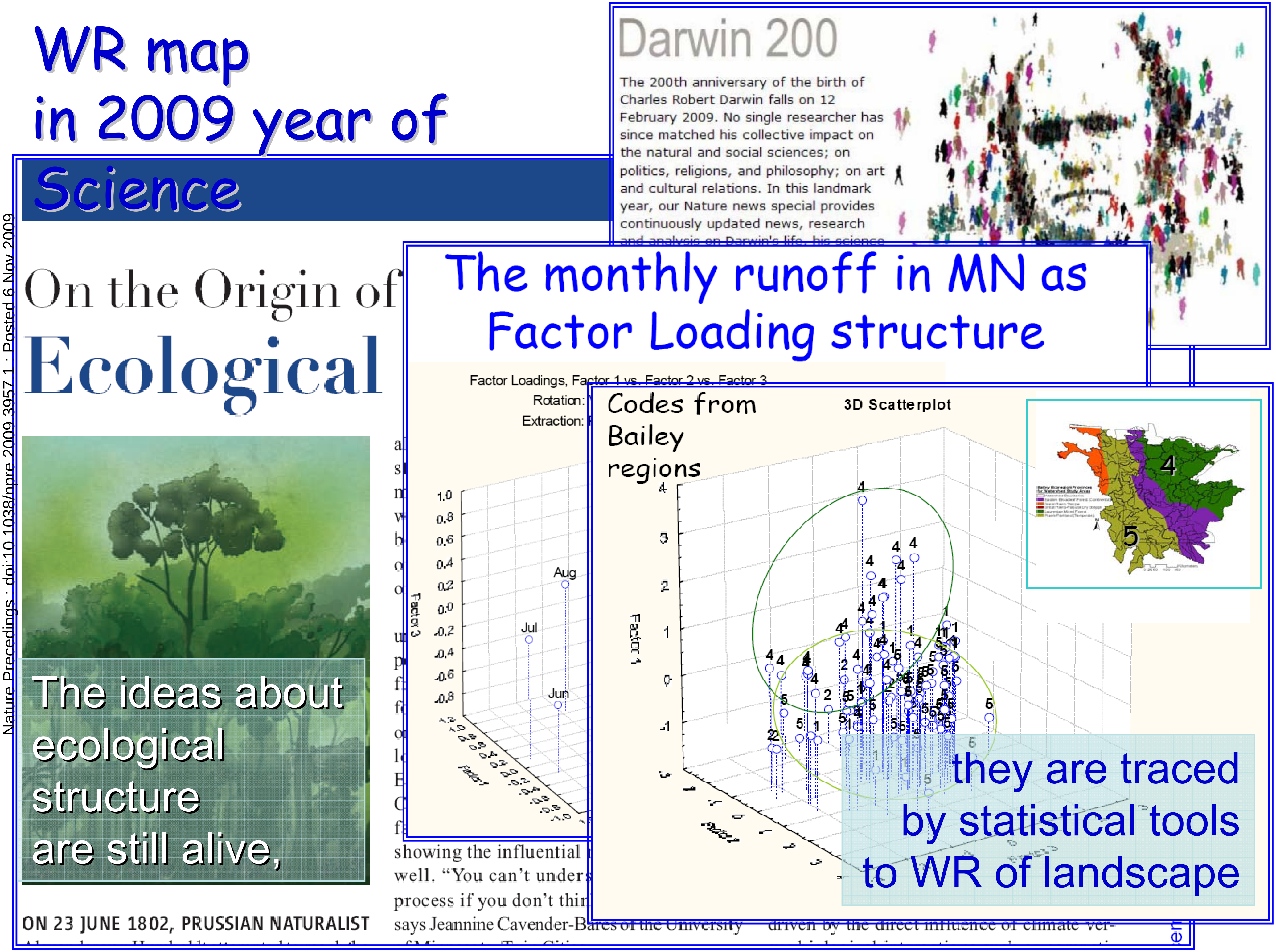
ORIGINS

"Alexander von Humboldt compared the influence of elevation on plant communities on Mount Chimborazo (*left*), Mont Blanc, and Sulitelma".



In the zone. Alexander von Humboldt (*above*, *left*) compared the influence of elevation on plant communities on Mount Chimborazo (*left*), Mont Blanc, and Sulitelma.

WR map in 2009 year of Science



1. The lithology of bedrock & thickness of quaternary sediments are the key landscapes properties that determine WR variability

2. The control over WR distribution belongs to geological boundaries

3. The regionalization on the WR map opens the way to study & monitor climate change for regional level

For discussion

Acknowledgement

System analysis of water recourses in Minnesota started in 1996 with support from faculty of Department of Geology University of Minnesota-Duluth

"Water Resource Sustainability" project, funded by the Legislative Citizens Commission on Minnesota Resources (2007-09) was the most resent face of the research

Additional funding & support for presented results provided by Provost Prof. Carol Peterson & Water Resource Institute of SDSU

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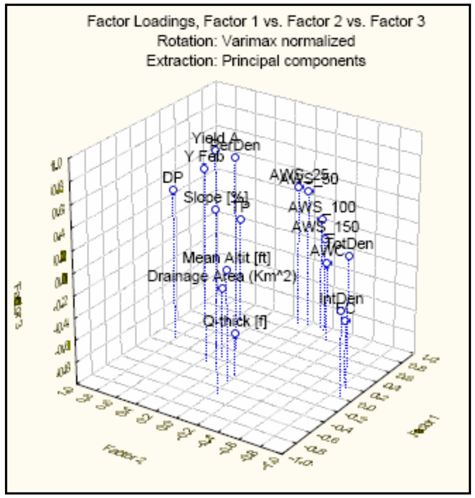
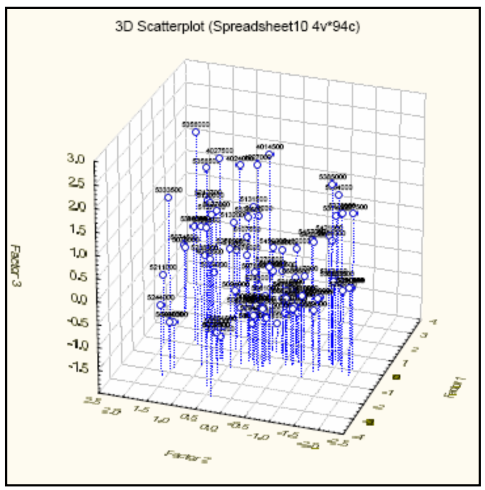
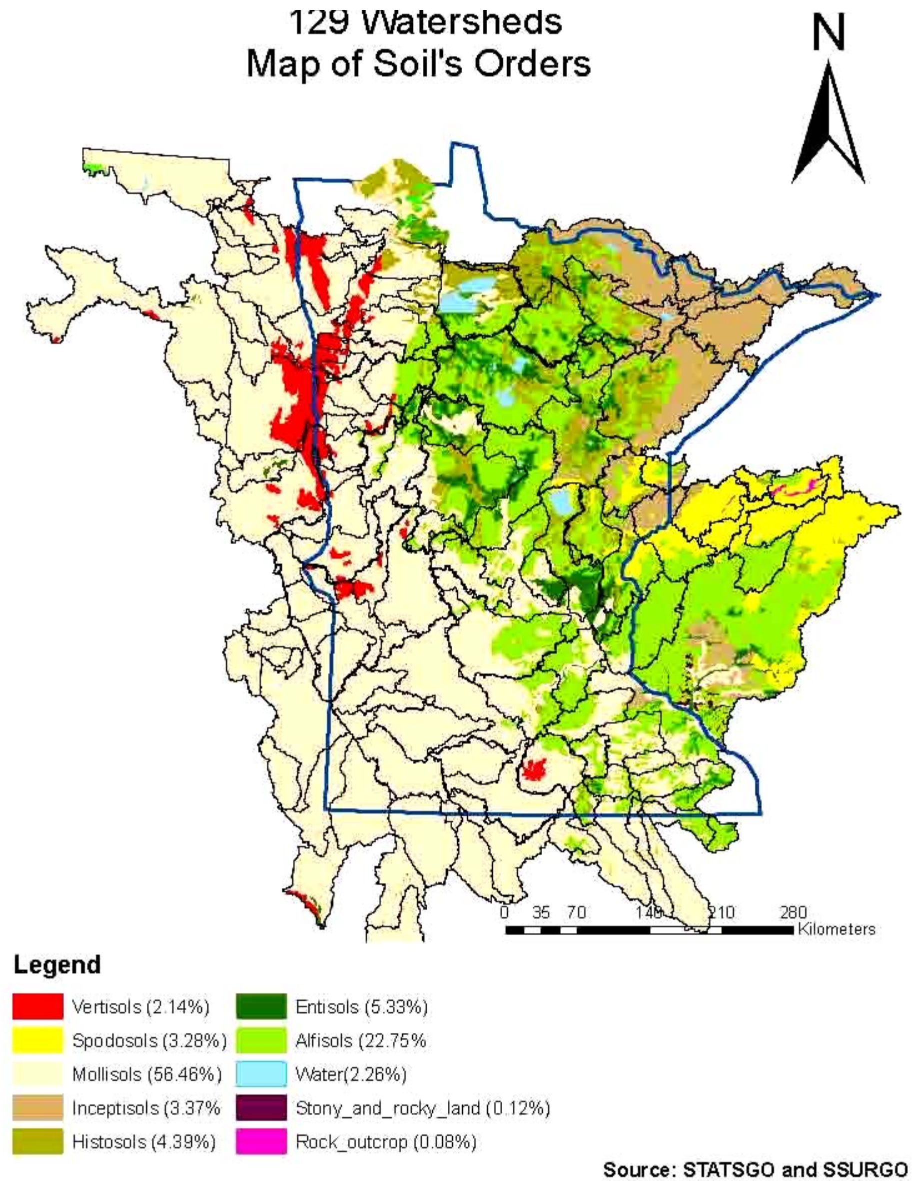
Additional slides in case of questions

Variable	Factor Loadings (Varimax normalized) Extraction: Principal components (Marked loadings are >.700000) Factor 1	Factor 2	Factor 3	Factor 4
Drainage Area (Km^2)	0.11	0.20	-0.19	-0.69
PerDen	0.23	-0.65	-0.34	0.34
IntDen	0.01	0.23	0.87	0.12
TotDen	0.15	-0.14	0.80	0.35
Mean Altit [ft]	-0.20	-0.21	0.08	-0.71
Slope [%]	-0.45	-0.70	0.04	-0.16
Yield A	-0.04	-0.89	-0.30	0.14
Y Feb	-0.06	-0.75	-0.38	0.02
DP	0.12	-0.29	-0.86	0.16
FC	0.26	0.39	0.81	-0.14
TP	0.68	0.08	-0.54	0.01
AWC	0.81	0.26	0.29	-0.13
AWS_25	0.92	-0.24	-0.12	0.13
AWS_50	0.95	-0.22	-0.03	0.10
AWS_100	0.97	0.01	0.09	0.05
AWS_150	0.95	0.15	0.16	0.01
Q-thick [f]	-0.18	0.68	-0.05	0.12
Expl.Var	5.17	3.34	3.62	1.37
Prp.Totl	0.30	0.20	0.21	0.08



Variable	Factor Loadings (Varimax normali Extraction: Principal components (Marked loadings are >.700000) Factor 1	Factor 2	Factor 3
Drainage Area (Km^2)	0.05	0.29	-0.37
PerDen	0.24	0.28	0.74
IntDen	0.03	-0.88	-0.23
TotDen	0.18	-0.84	0.19
Mean Altit [ft]	-0.27	0.02	0.01
Slope [%]	-0.48	-0.03	0.63
Yield A	-0.06	0.27	0.91
Y Feb	-0.08	0.36	0.74
DP	0.12	0.83	0.36
FC	0.26	-0.78	-0.44
TP	0.68	0.54	-0.05
AWC	0.80	-0.26	-0.29
AWS_25	0.92	0.11	0.28
AWS_50	0.95	0.03	0.25
AWS_100	0.97	-0.09	0.00
AWS_150	0.95	-0.14	-0.14
Q-thick [f]	-0.14	0.03	-0.63
Expl.Var	5.22	3.54	3.51
Prp.Totl	0.31	0.21	0.21

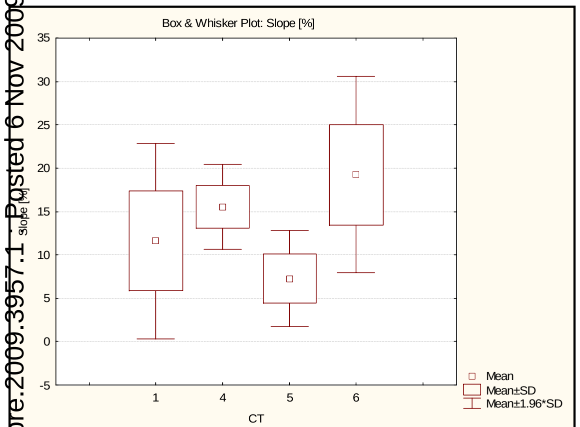




Research Task 4 for Taxonomic Soil Orders

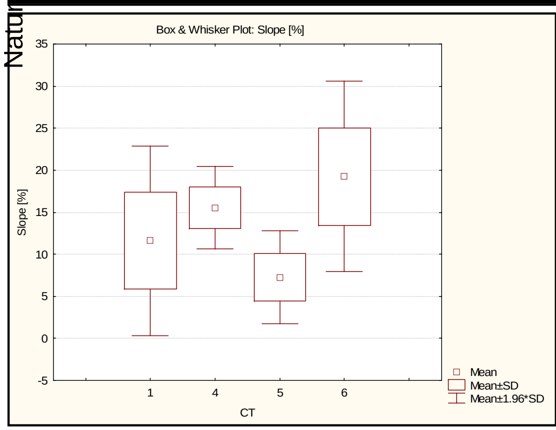
Multiple Comparisons z' values; Yield A (
Independent (grouping) variable: CT
Kruskal-Wallis test: H (3, N= 80) =44.55831 p =.0000

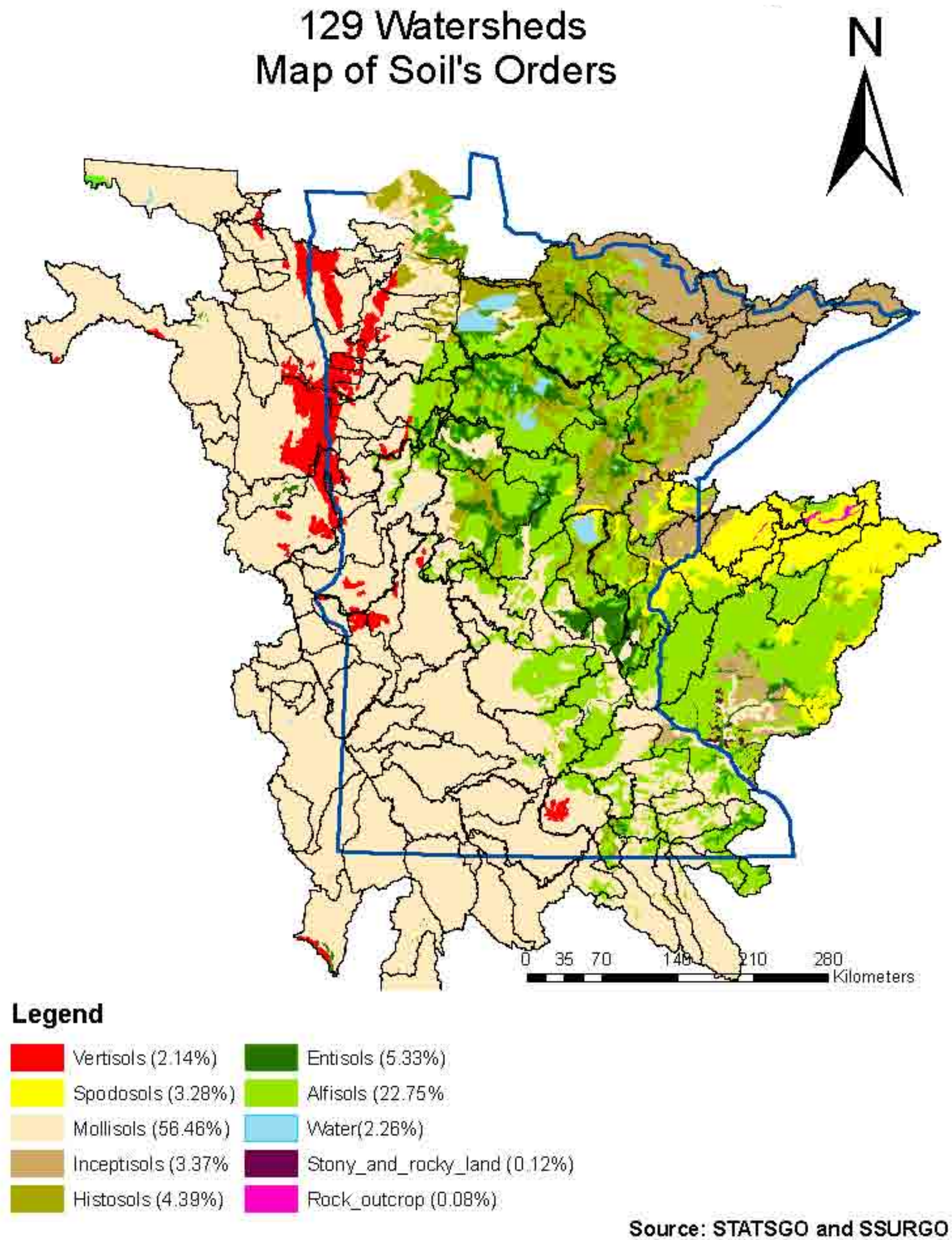
Depend.: Yield A	1 R:60.286	4 R:73.400	5 R:29.446	6 R:76.000
1		1.083228	4.441365	1.297986
4	1.083228		4.052391	0.176908
5	4.441365	4.052391		4.292104
6	1.297986	0.176908	4.292104	



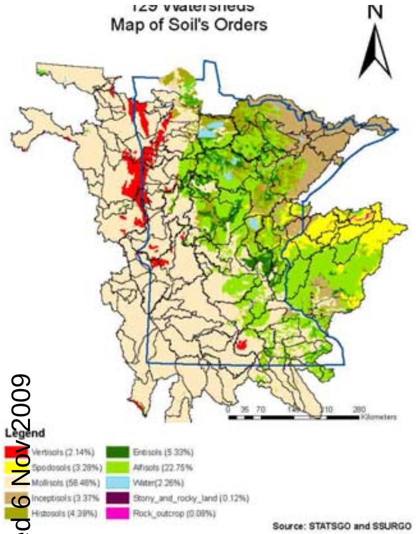
Multiple Comparisons z' values; Y Feb
Independent (grouping) variable: CT
Kruskal-Wallis test: H (3, N= 80) =43.70374 p =.0000

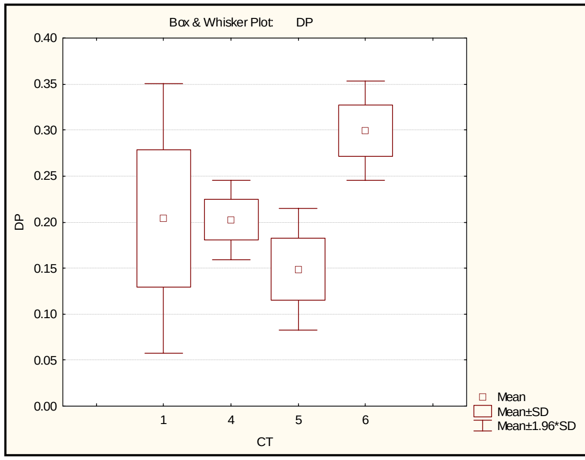
Depend.: Y Feb	1 R:62.000	4 R:67.700	5 R:29.482	6 R:76.500
1		0.470815	4.683107	1.197687
4	0.470815		3.523575	0.598764
5	4.683107	3.523575		4.334910
6	1.197687	0.598764	4.334910	

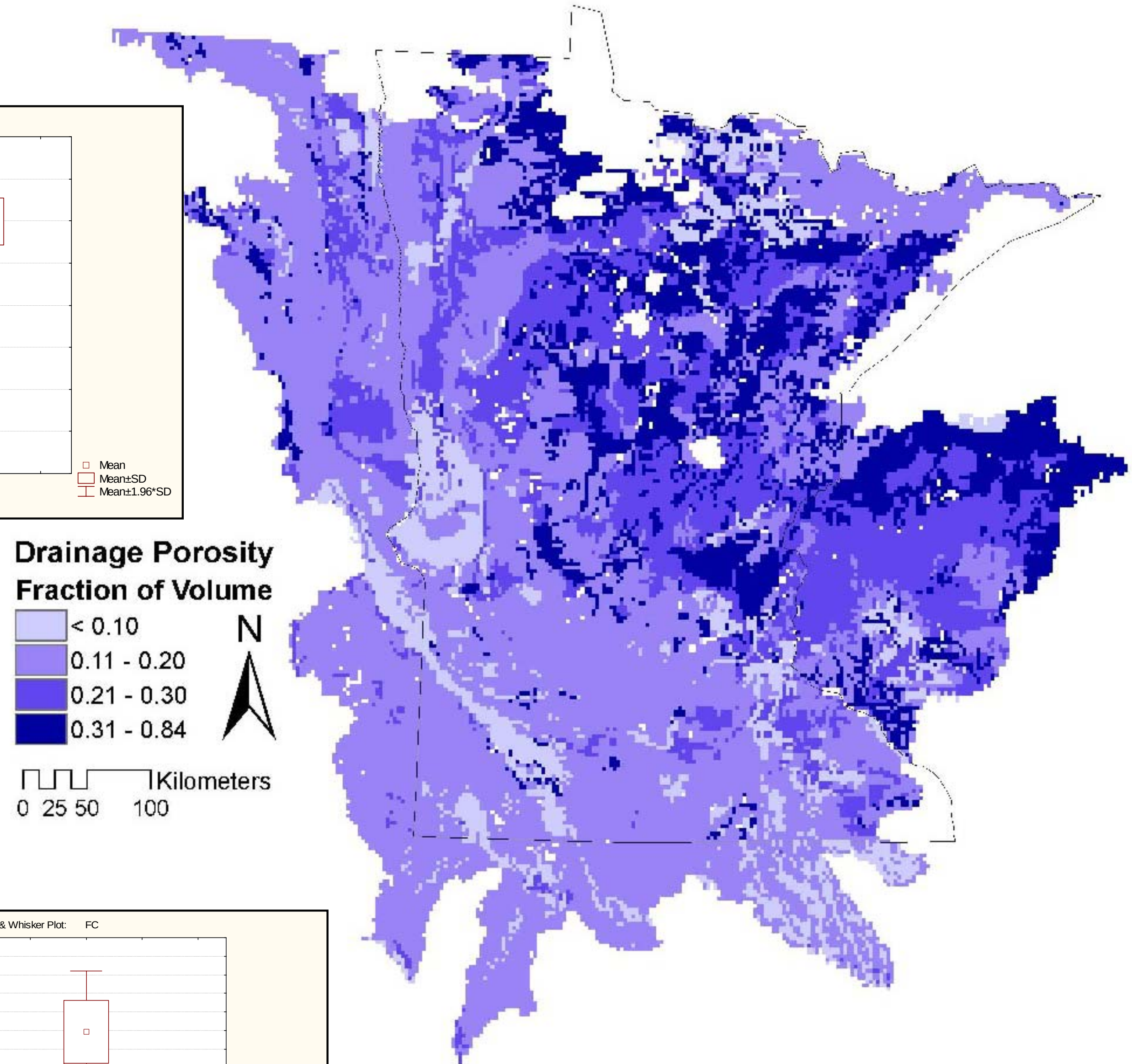




Annual & February Yield (1955-1979) for Taxonomic Soil Orders





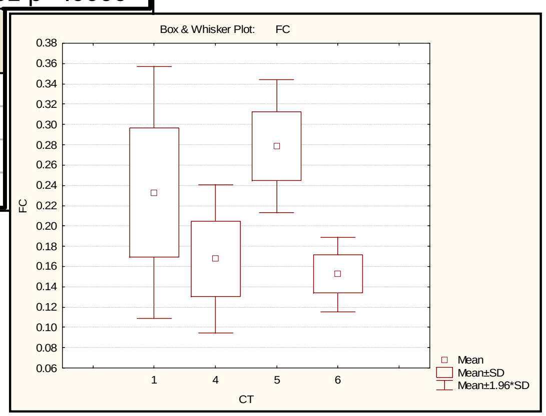


Multiple Comparisons z' values; DP
Independent (grouping) variable: CT
Kruskal-Wallis test: H (3, N= 80) =24.76407 p =.0000

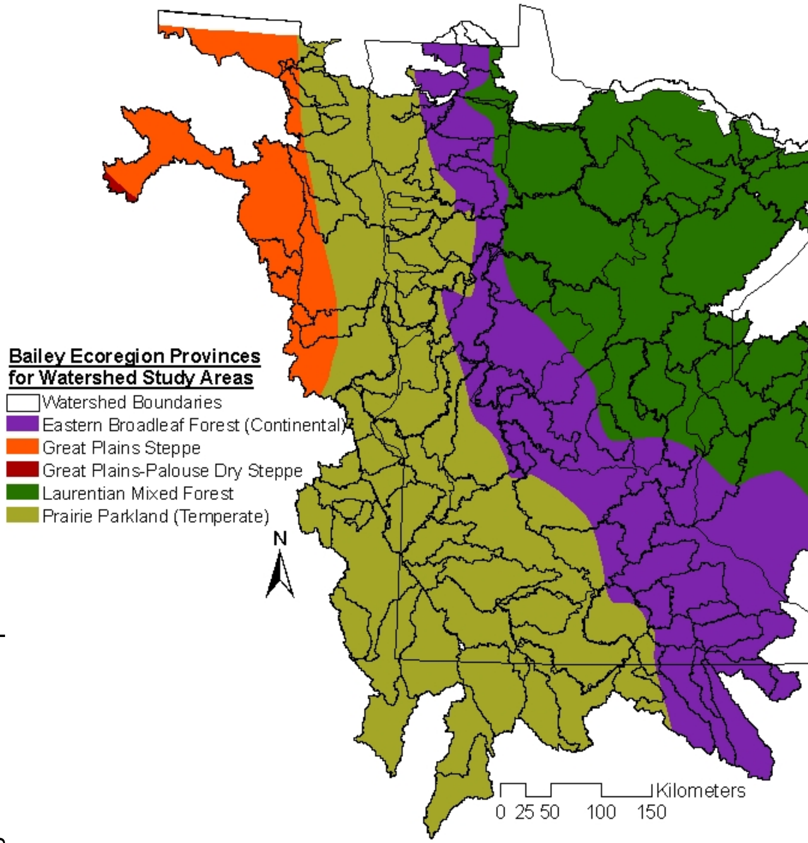
Depend.: DP	1 R:51.464	4 R:60.600	5 R:32.786	6 R:76.100
1		0.754602	2.690022	2.034888
4	0.754602		2.564396	1.054641
5	2.690022	2.564396		3.993451
6	2.034888	1.054641	3.993451	

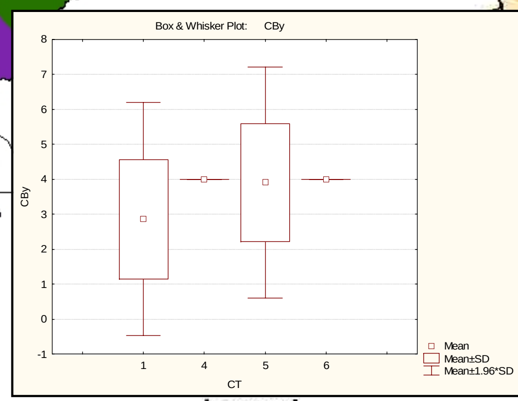
Multiple Comparisons z' values; FC
Independent (grouping) variable: CT
Kruskal-Wallis test: H (3, N= 80) =27.70361 p =.0000

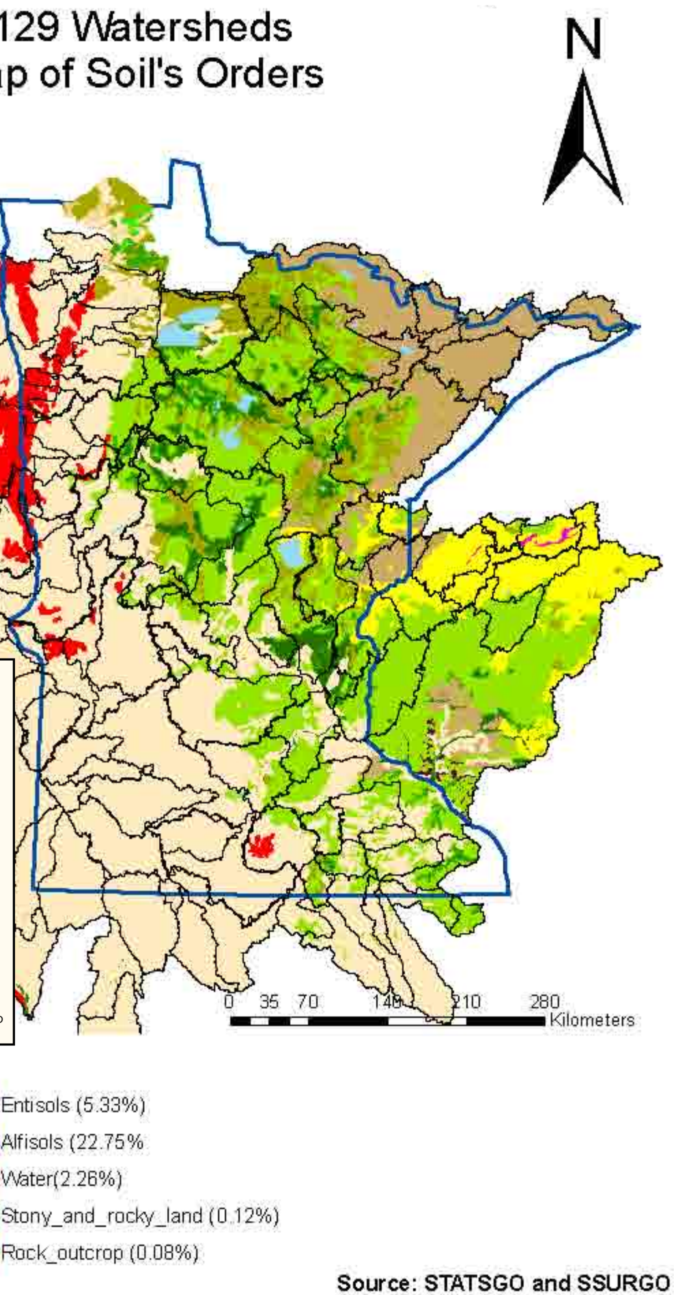
Depend.: FC	1 R:30.893	4 R:10.200	5 R:48.554	6 R:7.5000
1		1.709211	2.543434	1.932229
4	1.709211		3.536088	0.183712
5	2.543434	3.536088		3.785020
6	1.932229	0.183712	3.785020	



Drainage Porosity for Taxonomic Soil Orders







Multiple Comparisons p values (2-tailed); CBy
Independent (grouping) variable: CT
Kruskal-Wallis test: H (3, N= 80) =11.88055 p =.0078

Depend.: CBy	1 R:25.714	4 R:31.500	5 R:45.804	6 R:31.500
1		1.000000	0.022881	1.000000
4	1.000000		1.000000	1.000000
5	0.022881	1.000000		1.000000
6	1.000000	1.000000	1.000000	

Bailey's Eco Provinces & Taxonomic Soil Orders