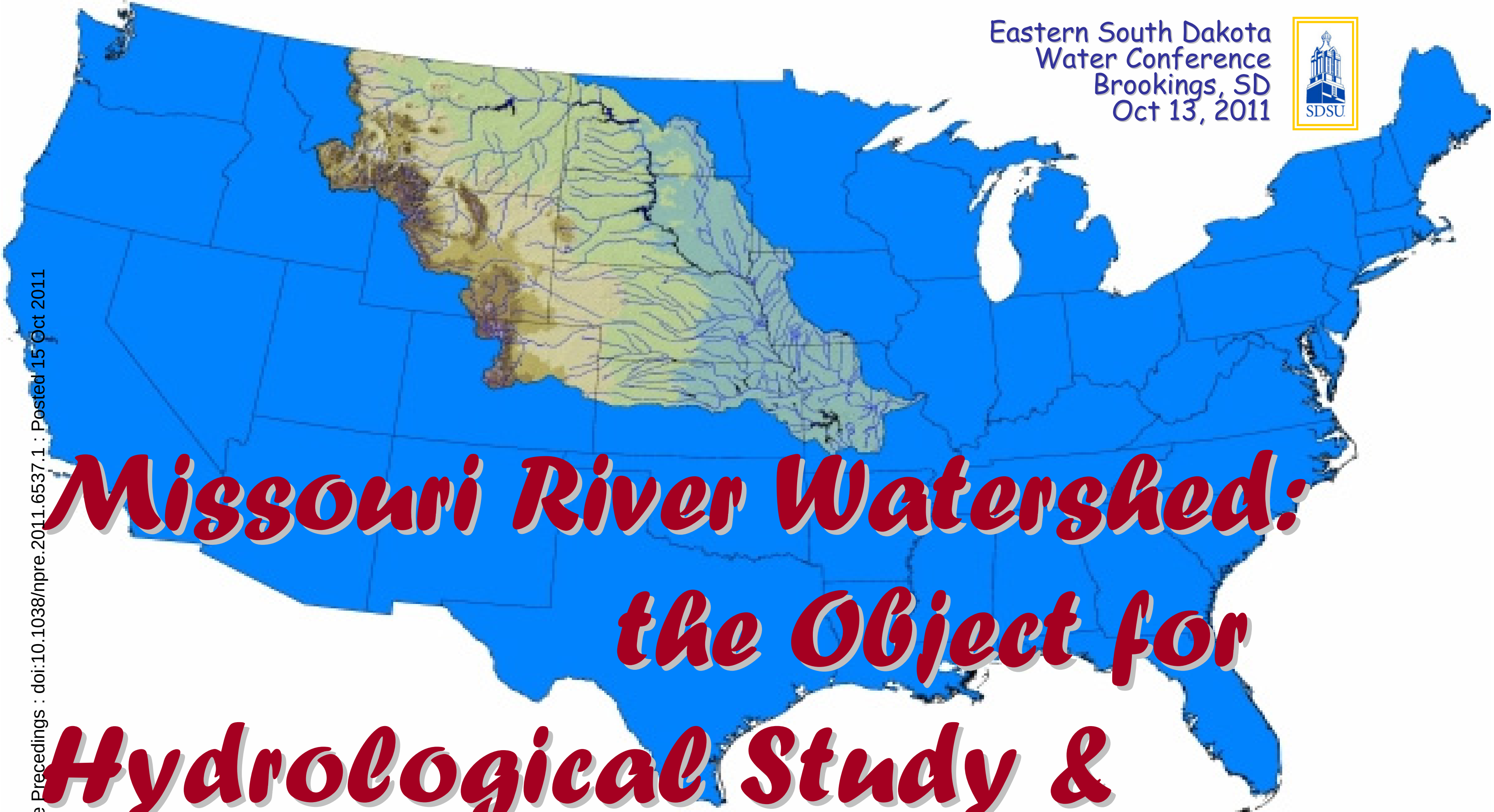
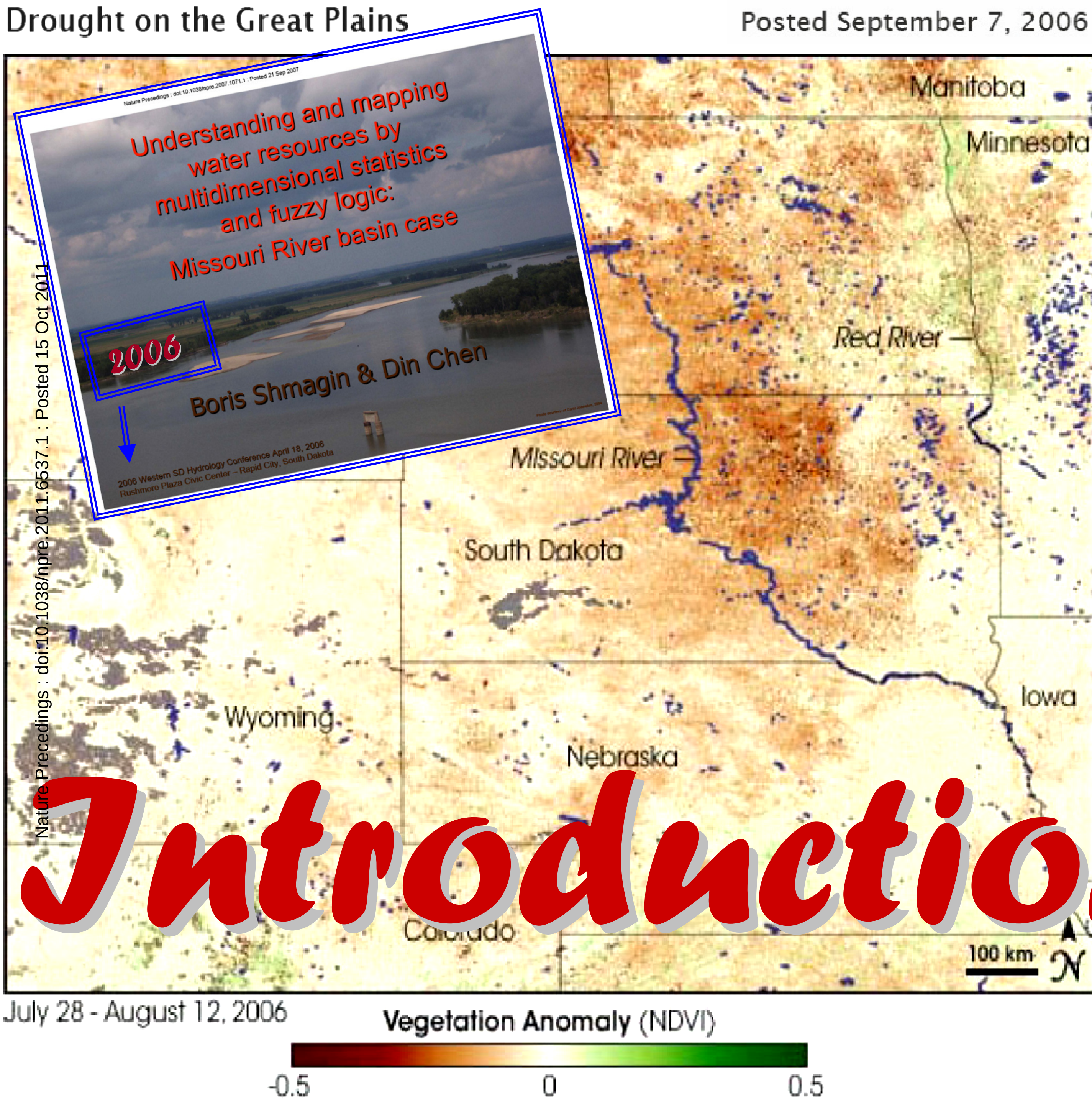
Eastern South Dakota
Water Conference
Brookings, SD
Oct 13, 2011



Missouri River Watershed: the Object for Hydrological Study & Uncertainty of Models

Boris Shmagin
WRI
SDSU

Introduction

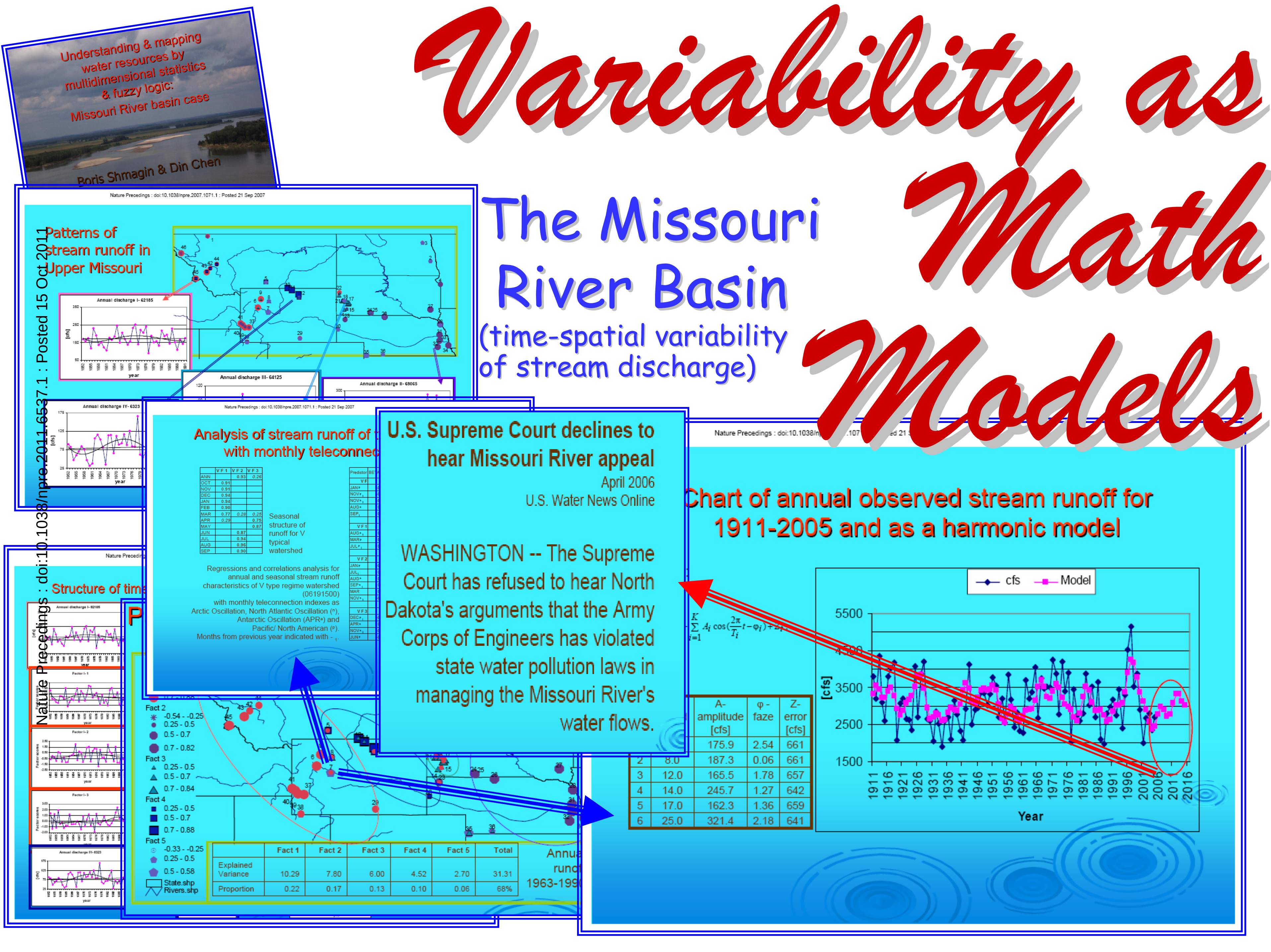


The goal:

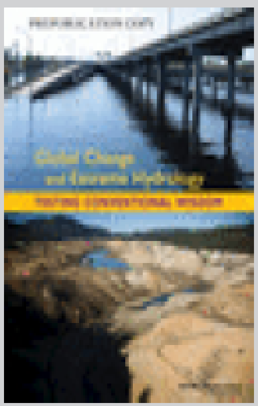
To talk on my experience of study river flow variability with use of science

The topics:

* Introduction: Philosophy for water development
* Knowledge & Uncertainty
* Results as Math Models
* Communicating the Knowledge
* Conclusions


Variability as Math Models
The Missouri River Basin
(time-spatial variability of stream discharge)
Understanding & mapping water resources by multidimensional statistics & fuzzy logic: Missouri River basin case
Boris Shmagin & Din Chen
Patterns of stream runoff in Upper Missouri
Analysis of stream runoff of
with monthly teleconnec
Structure of tim
U.S. Supreme Court declines to hear Missouri River appeal
April 2006
U.S. Water News Online
WASHINGTON -- The Supreme Court has refused to hear North Dakota's arguments that the Army Corps of Engineers has violated state water pollution laws in managing the Missouri River's water flows.
Chart of annual observed stream runoff for 1911-2005 and as a harmonic model
cfs
Model
[cfs]
Year
Seasonal structure of runoff for V typical watershed
Regressions and correlations analysis for annual and seasonal stream runoff characteristics of V type regime watershed (06191500) with monthly teleconnection indexes as Arctic Oscillation, North Atlantic Oscillation, Antarctic Oscillation (APR+) and Pacific/ North American. Months from previous year indicated with -
Explained Variance: Fact 1 10.29, Fact 2 7.80, Fact 3 6.00, Fact 4 4.52, Fact 5 2.70, Total 31.31
Proportion: 0.22, 0.17, 0.13, 0.10, 0.06, 68%
A-amplitude [cfs] | φ - faze | Z-error [cfs]
175.9 | 2.54 | 661
2 | 8.0 | 187.3 | 0.06 | 661
3 | 12.0 | 165.5 | 1.78 | 657
4 | 14.0 | 245.7 | 1.27 | 642
5 | 17.0 | 162.3 | 1.36 | 659
6 | 25.0 | 321.4 | 2.18 | 641
Annual discharge I- 62185
Annual discharge III- 64125
Annual discharge II- 68065
Annual discharge IY- 6323

From the National Research Consul



Global Change and Extreme Hydrology: Testing Conventional Wisdom

GeoJournal (2011) 76:401–415
DOI 10.1007/s10708-009-9257-x

Democracy or expertise? objectivity as an elusive ideal in the resolution of a Vermont land use dispute

Thomas H.N. Young

ISBN
978-0-309-21768-2

60 pages
6 x 9
PAPERBACK (2011)

Committee on Hydrologic Science; National Research Council

... our relation to the hydrologic system requires a modicum of reverence for rivers

"The management of resources cannot be carried out successfully if it is looked upon as just another facet of economics, administration, & politics."

"The great geographer, William Morris Davis, viewed the river system as having a life of its own. Its *youthful headwaters*, he said, are steep and rugged. It rushes toward the sea, eroding bed & bank on its way. In its *central part, it is mature*, winding sedately through wide valleys adjusted to its duty of transporting water & sediment. *Near its mouth* it has reached, in its *old age*, a nearly level plain through which it wanders in a somewhat aimless course toward final extinction as it joins the ocean that had provided the sustaining waters through its whole life span."

"Man's *engineering capabilities are* nearly *limitless*. Our *economic views are* too *insensitive* to be the only criteria for judging the health of the river organism.

What is needed is a gentler basis for perceiving the effects of our engineering capabilities. This more humble view of our relation to the hydrologic system requires a modicum of reverence for rivers."

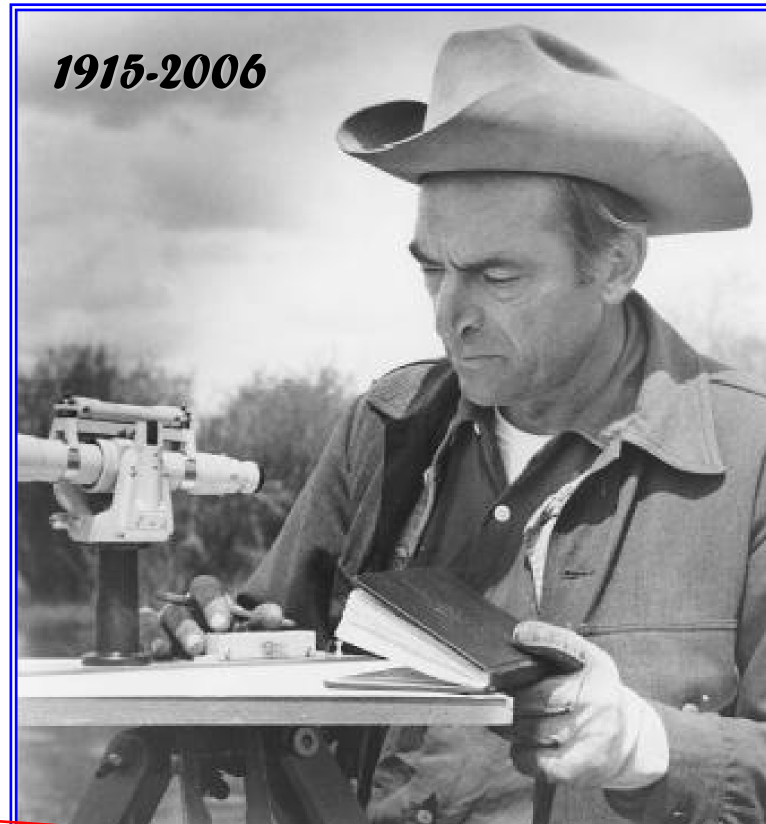
A reverence for rivers

Luna B. Leopold

Keynote address to the Governor's Conference on the California Drought

Los Angeles, California, March 7, 1972

Lula Leopold



The Concept of Entropy in Landscape Evolution

By LUNA B. LEOPOLD and WALTER

THEORETICAL PAPERS IN THE

GEOMORPHIC SCIENCES

GEOLOGICAL SURVEY PROFESSIONAL P

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 19

PHILOSOPHY FOR WATER DEVELOPMENT

Chief Hydraulic Engineer
Room 2227 GS Bldg.
Geological Survey

DO

DEPARTMENT OF THE INTERIOR

INFORMATION SERVICE

For Release to PM's, MARCH 28, 1961

ADDRESS BY LUNA B. LEOPOLD AND E. L. HENDRICKS, GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR, AT THE NATIONAL WATER RESEARCH SYMPOSIUM, WASHINGTON, D. C., MARCH 28, 1961

PHILOSOPHY FOR WATER DEVELOPMENT

The Knowledge & the Uncertainty

The Uncertainty & Information

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Information Sciences 172 (2005) 1–40
INFORMA... SCIENCE... AN INTERNATIONAL JOU...
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Toward a generalized theory of uncertainty (GTU)—an outline

Lotfi A. Zadeh
Berkeley initiative in Soft Computing (BISC), C...
and the Electronics Research Laboratory, Department o...
615 Soda Hall, Berkeley, CA 9472...

Received 21 December 2004; accepted ...

Dedicated to Didier Dubois, Henri Prade and th...
Richard Bellman and Herbert ...

Abstract

It is a deep-seated tradition in science to view uncer... theory. The generalized theory of uncertainty (GTU...

L. A. Zadeh / Information Sciences 172 (2005) 1–40

INFORMATION

measurement-based | **perception-based linguistic**

- **It is very warm**
- **Most Swedes are tall**
- **probability is high**
- **it is cloudy**
- **traffic is heavy**
- **it is hard to find parking near the campus**

...tion may be viewed as a special case of

...n is intrinsically imprecise

...ed vs. perception-based information.

INFORMATION SCIENCES 8, 199–249 (1975) 199

The Concept of a Linguistic Variable and its Application to Approximate Reasoning—I

L. A. ZADEH
Computer Sciences Division, Department of Electrical Engineering and Computer Sciences, and the Electronics Research Laboratory, University of California, Berkely, California 94720

ABSTRACT

By a *linguistic variable* we mean a variable whose values are words or sentences in a natural or artificial language. For example, *Age* is a linguistic variable if its values are linguistic rather than numerical, i.e., *young, not young, very young, quite young, old, not very old and not very young,* etc., rather than 20, 21, 22, 23, ... In more specific terms,

Information in the Language

4 Jürgen Van de Walle

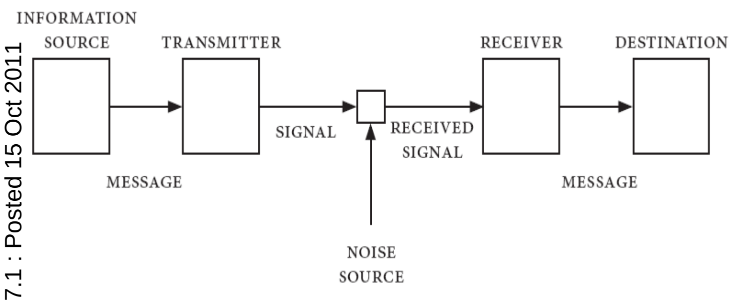
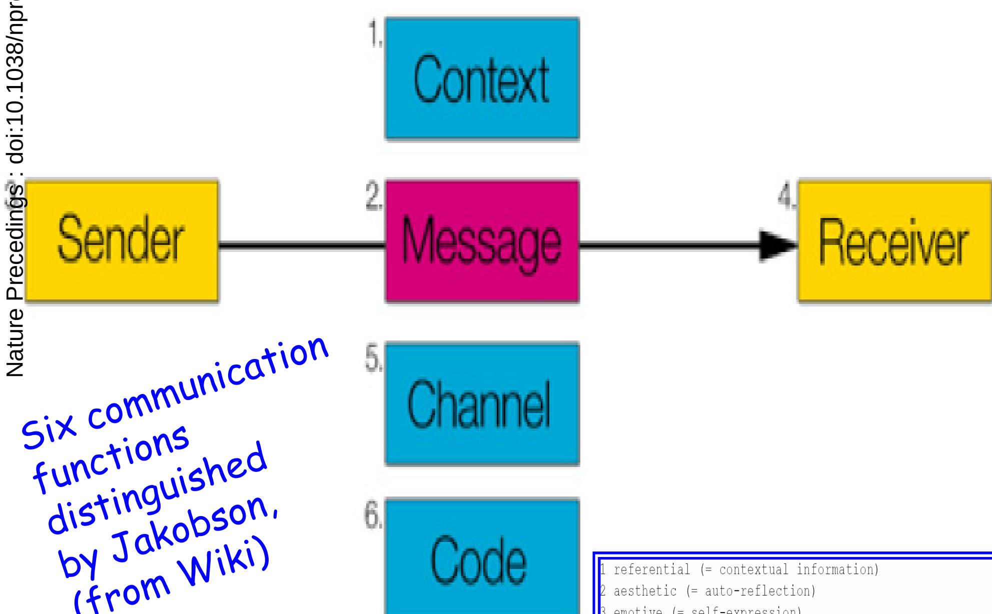


Figure 1. Shannon's communication channel

Roman Jakobson, cybernetics and information theory
A critical assessment[1]

Walle

Folia Linguistica Historica 29/1–2 (2008), 1–37.



Six communication functions distinguished by Jakobson, (from Wiki)

1 referential (= contextual information)
2 aesthetic (= auto-reflection)
3 emotive (= self-expression)
4 conative (= vocative or imperative addressing of receiver)
5 phatic (= checking channel working)
6 metalingual (= checking code working) [2]

"In cognitive linguistics as in cognitive science, the **human mind** is considered to be an **information-processing device** (Stillings 1995), & **language** is viewed as a **vehicle for communicating information**."

From: J. Van de Walle, 2008

The Science & the Language

John R. Searle Page 1 6 November, 2006
WhatisLanguageforLandauFNLSavas

What is Language: Some Preliminary Remarks[1]

By John R. Searle

Copyright John R. Searle

I. Naturalizing Language

I believe that the greatest achievements in philosophy over the past hundred or one hundred and twenty five years have been in the philosophy of language. Beginning with Frege, who invented the subject, and continuing through Russell, Wittgenstein, Quine, Austin and their successors, right to the present day, there is no branch of philosophy with so much high quality work as the philosophy of language. In my view, the only achievement comparable to those of the great philosophers of language is Rawls's reinvention of the subject of political philosophy (and therefore implicitly the subject of ethics). But with this one possible exception, I think that work in the philosophy of language is at the top of our achievements.

"Chomsky argues that no science has a mechanical procedure for discovering the truth anyway"

"the proper object of study was **the speaker's underlying knowledge of the language**, his "linguistic competence" that enables him to produce & understand sentences he has never heard before"

From: *"Chomsky's Revolution in Linguistics"* by John R. Searle
The New York Review of Books, June 29, 1972

Statistics & Uncertainty

The Statistician (2000)
49, *Part* 3, *pp.* 293–337

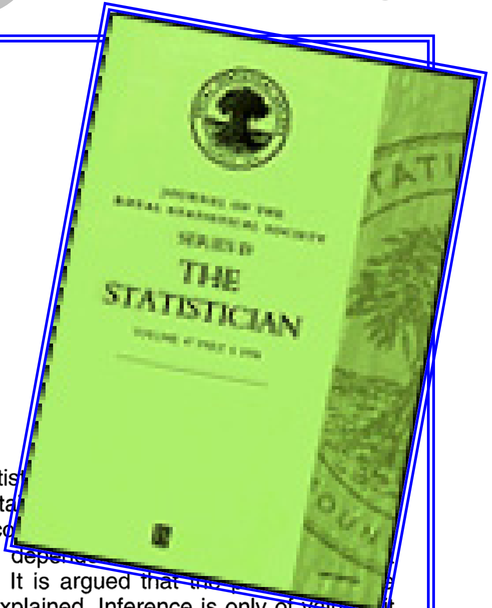
The philosophy of statistics

Dennis V. Lindley
Minehead, UK

[Received June 1999]

Summary. This paper puts forward an overall view of statis
study of uncertainty. The many demonstrations that uncerta
the rules of the probability calculus are summarized. The co
firmly based on probability alone. Progress is therefore depe
probability model; methods for doing this are considered. It is argued that
personal. The roles of likelihood and exchangeability are explained. Inference is only of value
can be used, so the extension to decision analysis, incorporating utility, is related to risk and to the
use of statistics in science and law. The paper has been written in the hope that it will be intelligible
to all who are interested in statistics.

Keywords: Conglomerability; Data analysis; Decision analysis; Exchangeability; Law; Likelihood; Models; Personal probability; Risk; Scientific method; Utility

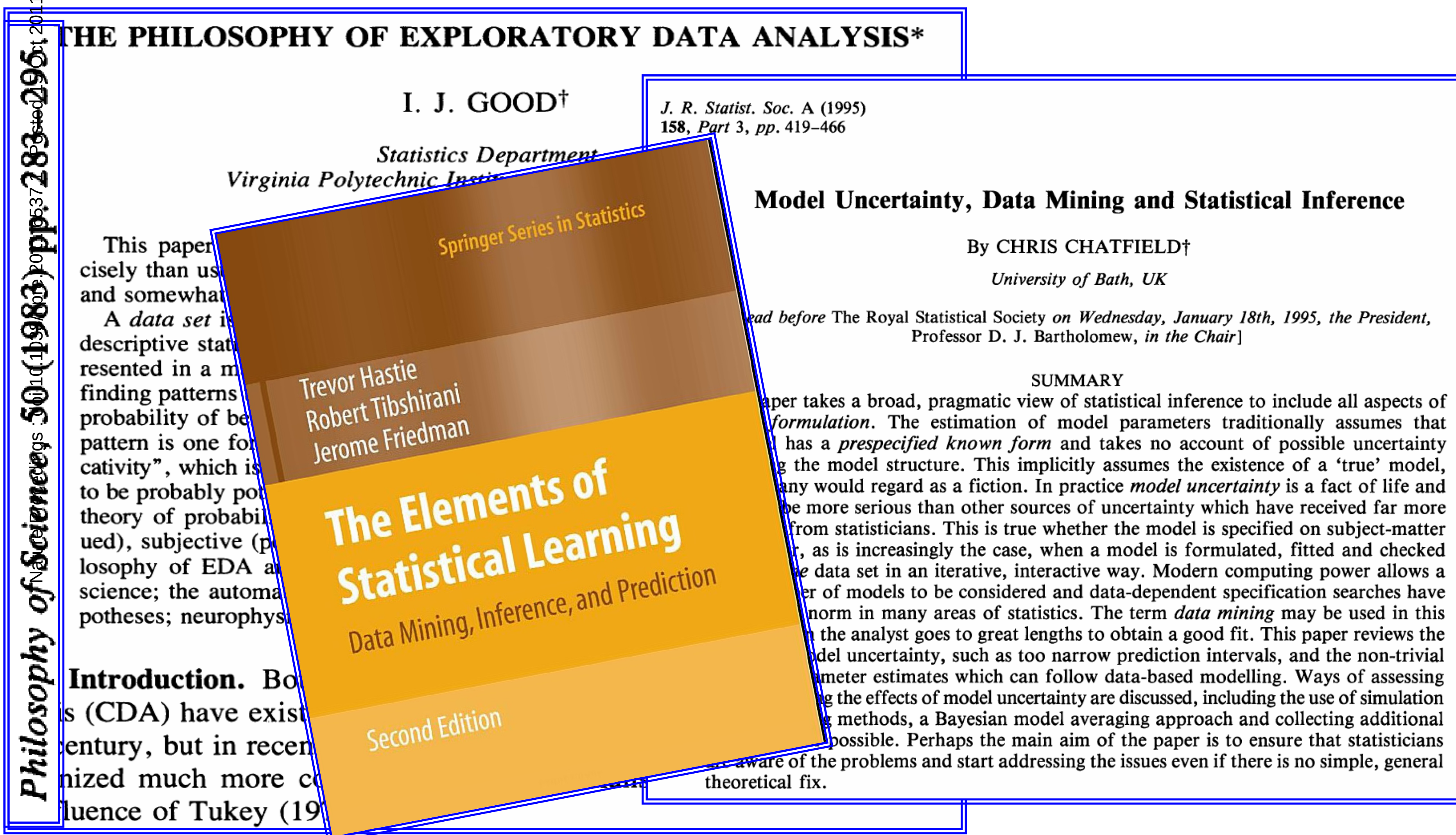


The statistician's task is to articulate the scientist's uncertainties in the **language** of probability… **A model is merely your reflection of reality &, like probability, it describes neither you nor the world, but only a relationship between you & that world.”** (p. 303)

“… **data analysis assists in the formulation of a model** & is an activity that precedes the formal probability calculations that are needed for inference.” (p. 305)

“**Statisticians are not masters in their own house.**
Their task is to help the client to handle the uncertainty that they encounter.
The **'you'** of the analysis is the client, not the statistician.” (p. 318)

From Data Analysis to Statistical Learning



ADDRESSING THE COMPLEXITY OF THE EARTH SYSTEM

BY CARLOS NOBRE, GUY P. BRASSEUR, MELVYN A. SHAPIRO, MYANNA LAHSEN, GILBERT BRUNET, ANTONIO J. BUSALACCHI, KATHY HIBBARD, SYBIL SEITZINGER, KEVIN NOONE, AND JEAN P. OMETTO

al, and societal processes would accelerate
th system prediction.

OCTOBER 2010 BAMS

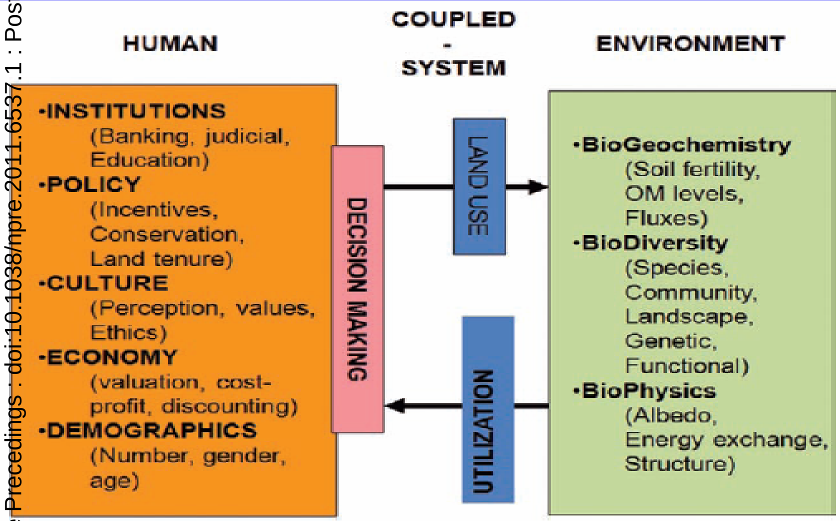
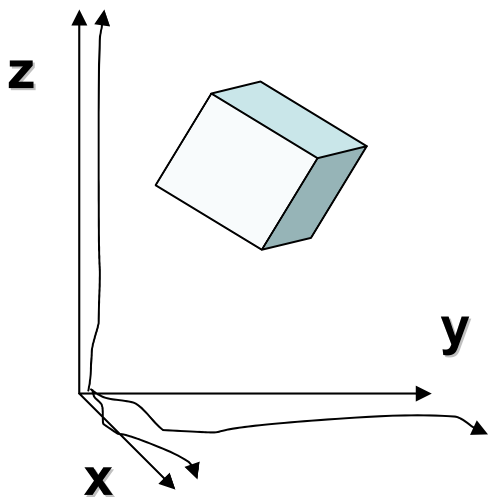


FIG. 4. An example of a model of a coupled human–environmental system that accounts for the influences of one subset of human actions (land use) on the natural systems and for the role of environmental goods and services for human welfare (utilization). [While "culture" is listed as a separate factor in this list, it is worth emphasizing that culture is a pervasive factor that also shapes institutions, economy, science, etc. (Proctor 1998).]

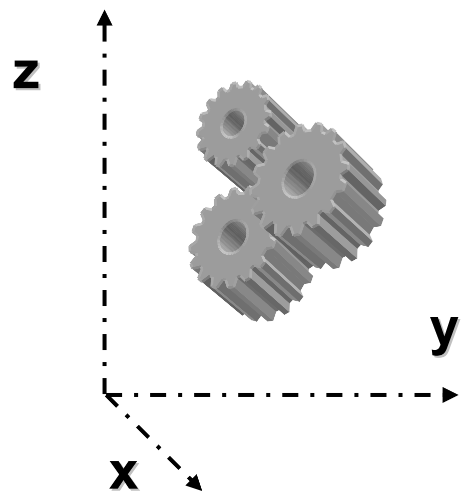
1394 | BAMS OCTOBER 2010

& of the Watershed

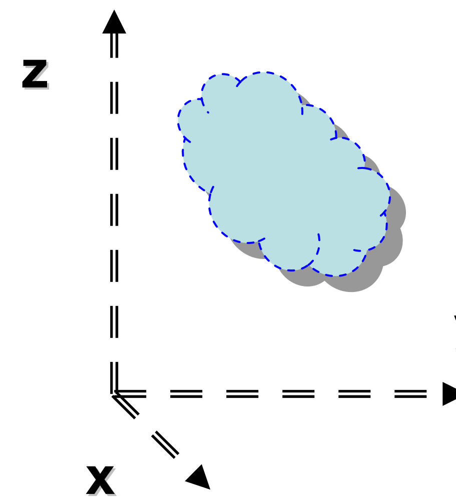
The Uncertainty & Different Systems of Coordinates



Mathematical & physical objects are abstractions & "have" the principle of uncertainty

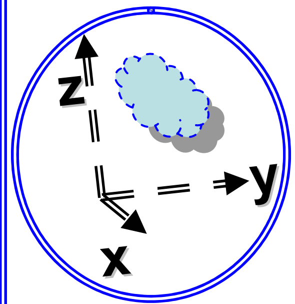


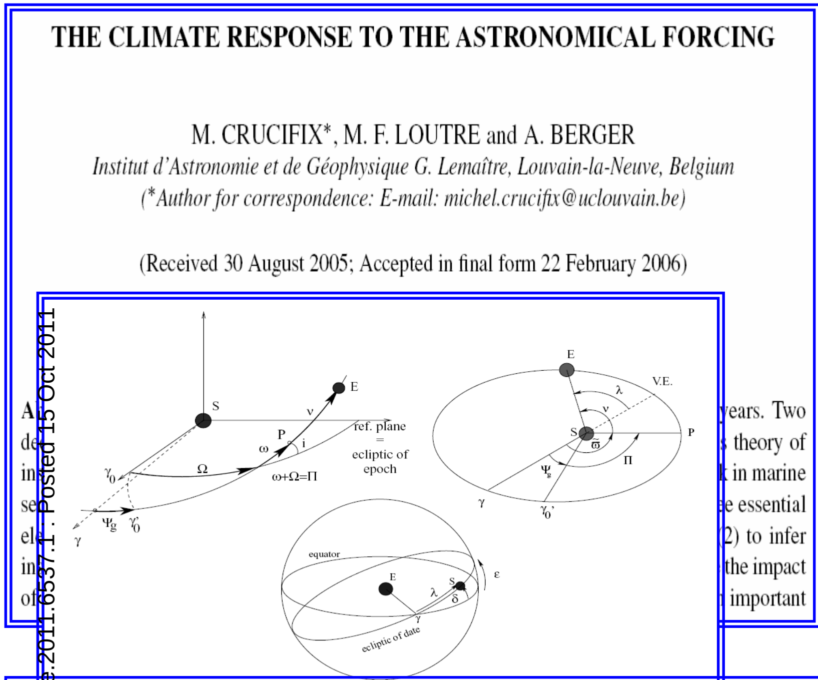
Technological objects have the errors of measurement



Natural objects have fuzzy boundaries in their own coordinates of multi-dimensional process & nonstationary axes

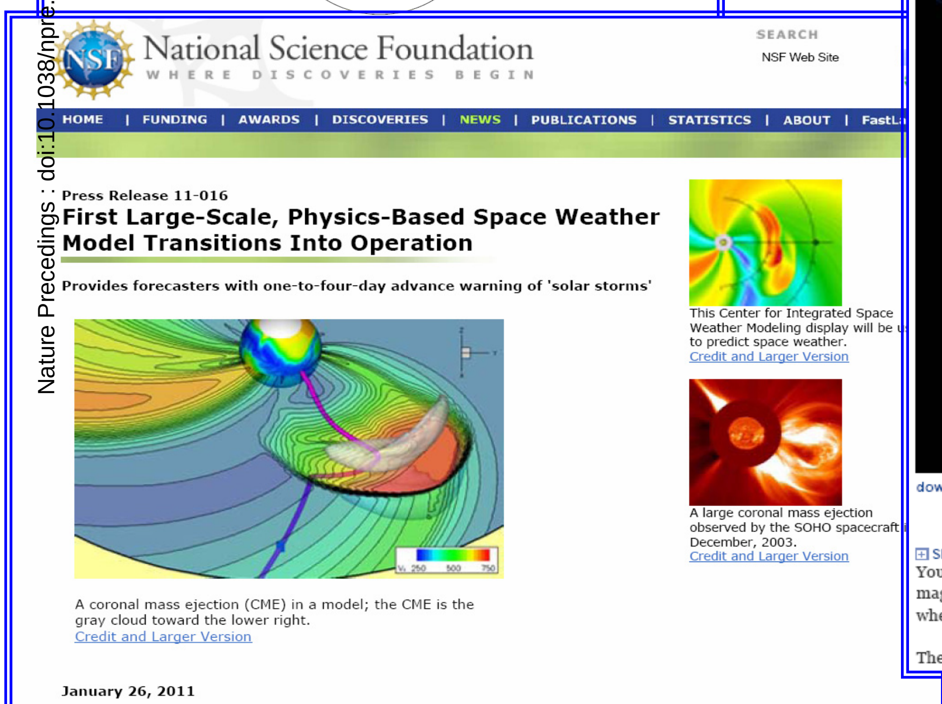
Coordinates for the Earth




THE CLIMATE RESPONSE TO THE ASTRONOMICAL FORCING

M. CRUCIFIX*, M. F. LOUTRE and A. BERGER
Institut d'Astronomie et de Géophysique G. Lemaître, Louvain-la-Neuve, Belgium
*(*Author for correspondence: E-mail: michel.crucifix@uclouvain.be)*

(Received 30 August 2005; Accepted in final form 22 February 2006)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Press Release 11-016
First Large-Scale, Physics-Based Space Weather Model Transitions Into Operation

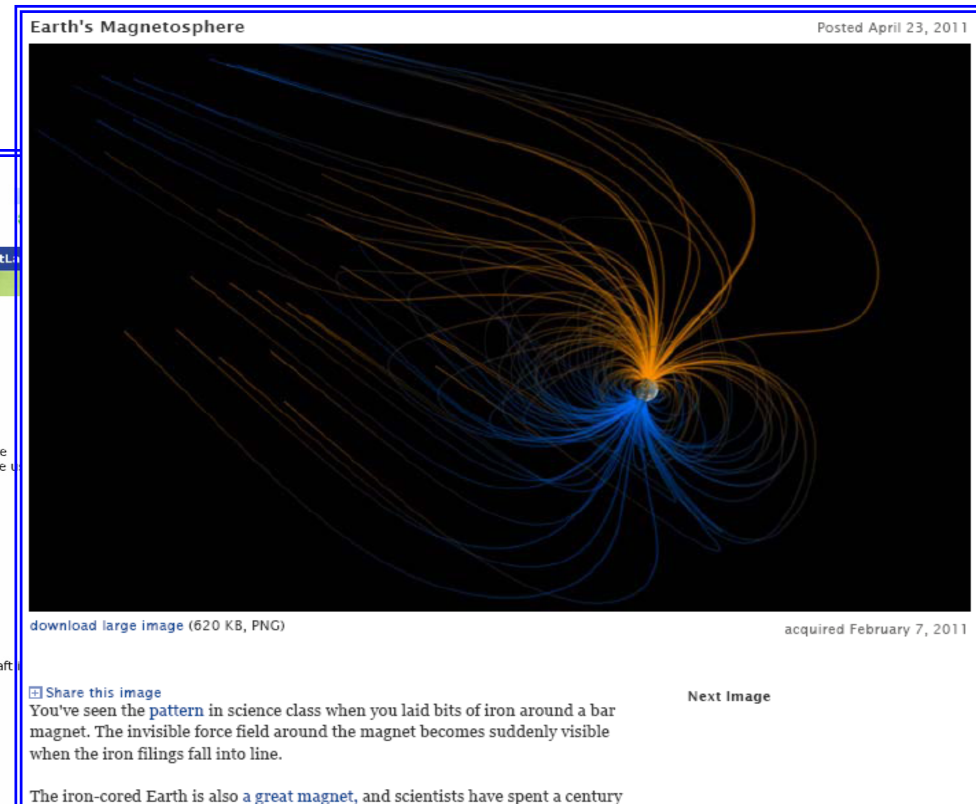
Provides forecasters with one-to-four-day advance warning of 'solar storms'

A coronal mass ejection (CME) in a model; the CME is the gray cloud toward the lower right.
Credit and Larger Version

This Center for Integrated Space Weather Modeling display will be u
to predict space weather.
Credit and Larger Version

A large coronal mass ejection observed by the SOHO spacecraft
December, 2003.
Credit and Larger Version

January 26, 2011


Earth's Magnetosphere

Posted April 23, 2011

download large image (620 KB, PNG)

acquired February 7, 2011

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Next Image

You've seen the pattern in science class when you laid bits of iron around a bar magnet. The invisible force field around the magnet becomes suddenly visible when the iron filings fall into line.

The iron-cored Earth is also a great magnet, and scientists have spent a century

The Coordinates on the Earth

Taking the "Boulder" Step From Static to Dynamic Geoid

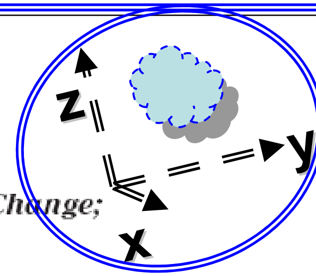
2009 Workshop on Monitoring North American Geoid Change; Boulder, Colorado, 21–23 October 2009

PAGE 46

and Mexico) and Europe specializing in sat-

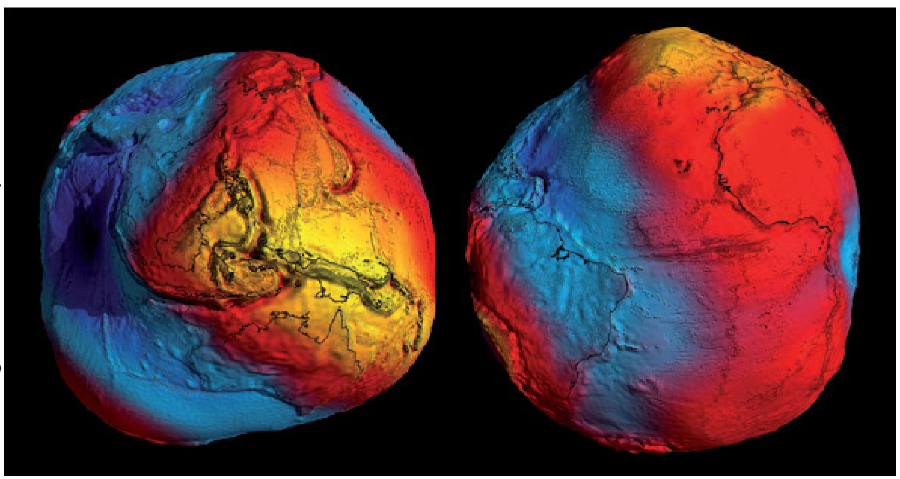
...ry as well as

...d in Colorado.



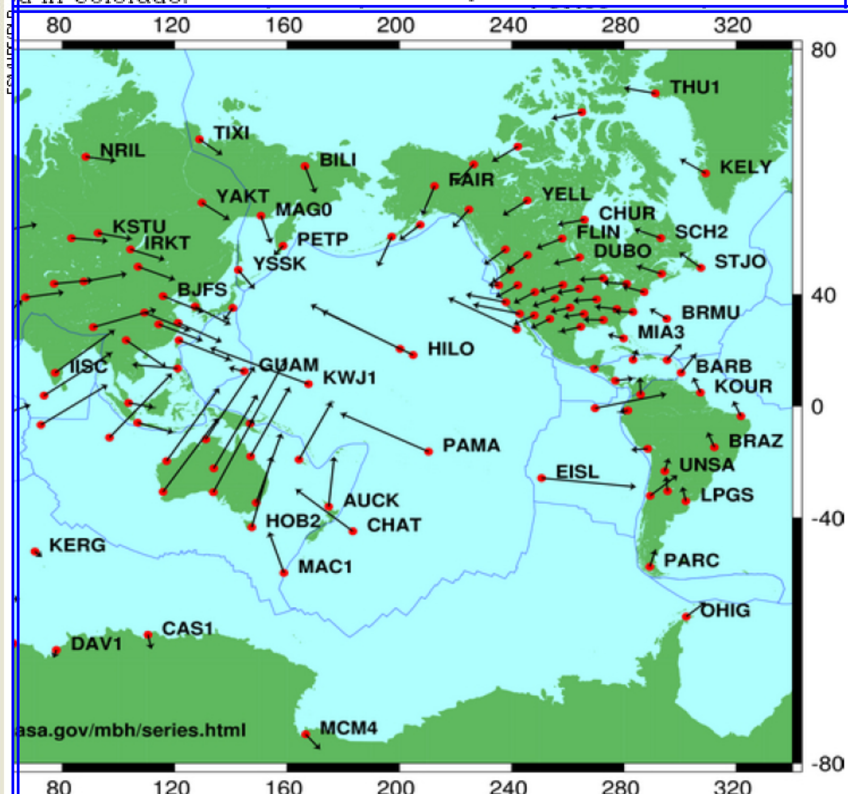
...out over the

account deep tectonic mass changes (such as the continental uplift seen in the region of Hudson Bay and southern Canada) while separating out the small-scale or episodic geophysical (e.g., water table or magma) changes and weather phenomena. The means by which absolute and rela-



The pull of the planet

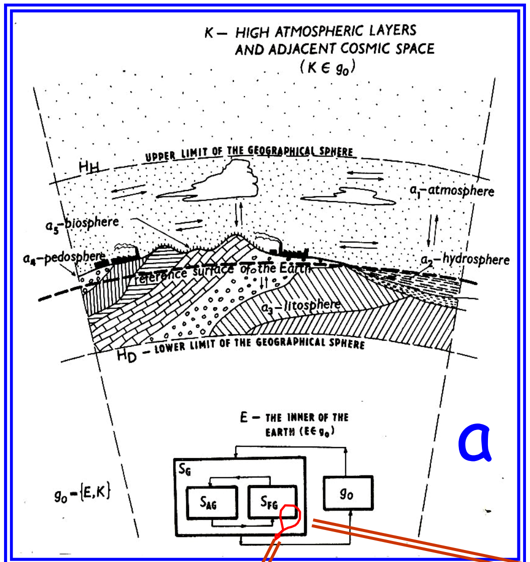
The most detailed map of Earth's gravity ever made was unveiled last week in Munich, Germany, when researchers presented eight months' worth of data from the European Space Agency's Gravity Field and Steady-State Ocean Circulation Explorer (GOCE), a satellite launched in 2009. GOCE maps subtle variations in Earth's gravitational field that arise from the planet's uneven distribution of mass. The result is a 'geoid' (pictured — variations exaggerated 10,000 times), showing the world if it were covered by an ocean whose height was influenced only by gravity. This reference allows geoscientists to precisely measure the heights of shifting oceans and continents. GOCE will continue mapping until the end of 2012.



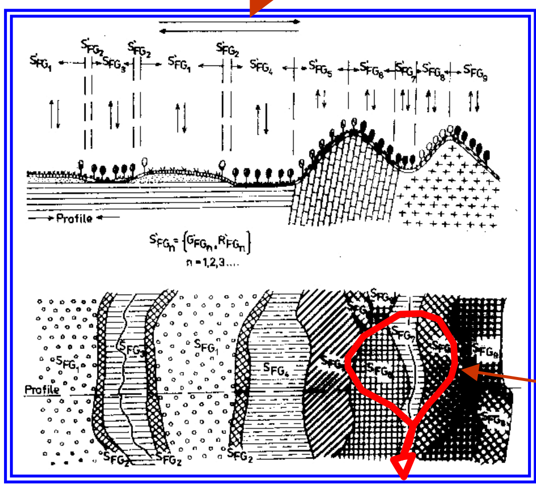
avimetric noise

Columbus

Cybernetic Model (a) for Watershed in Landscape, with Map of Conditions (b) & Multilayer Map (c)

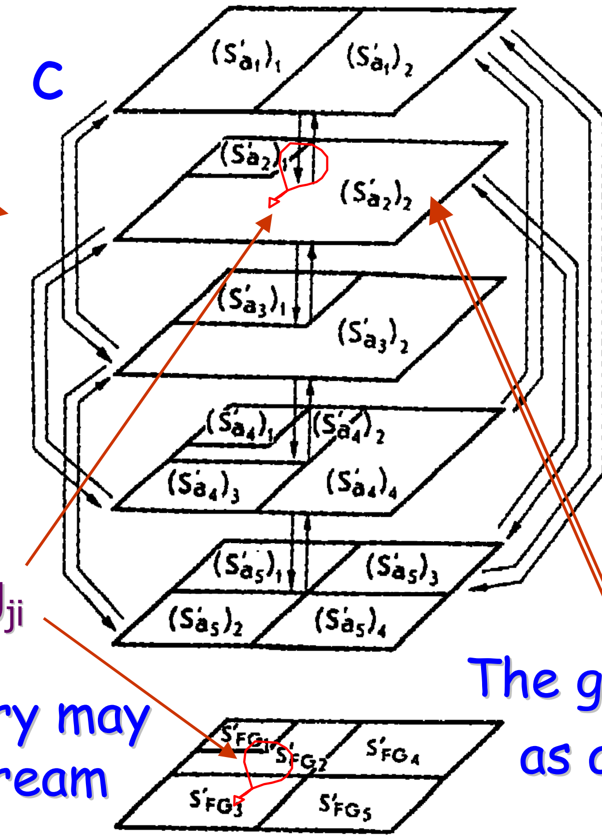


a



b

c



g_{ji}

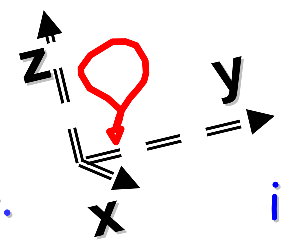
System of Physical Geography Sphere (S_{FG}) with five independent elements:
a_1- atmosphere,
a_2- hydrosphere,
a_3- lithosphere,
a_4- pedosphere,
a_5- biosphere
(after Krcho, 1978)

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}.

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

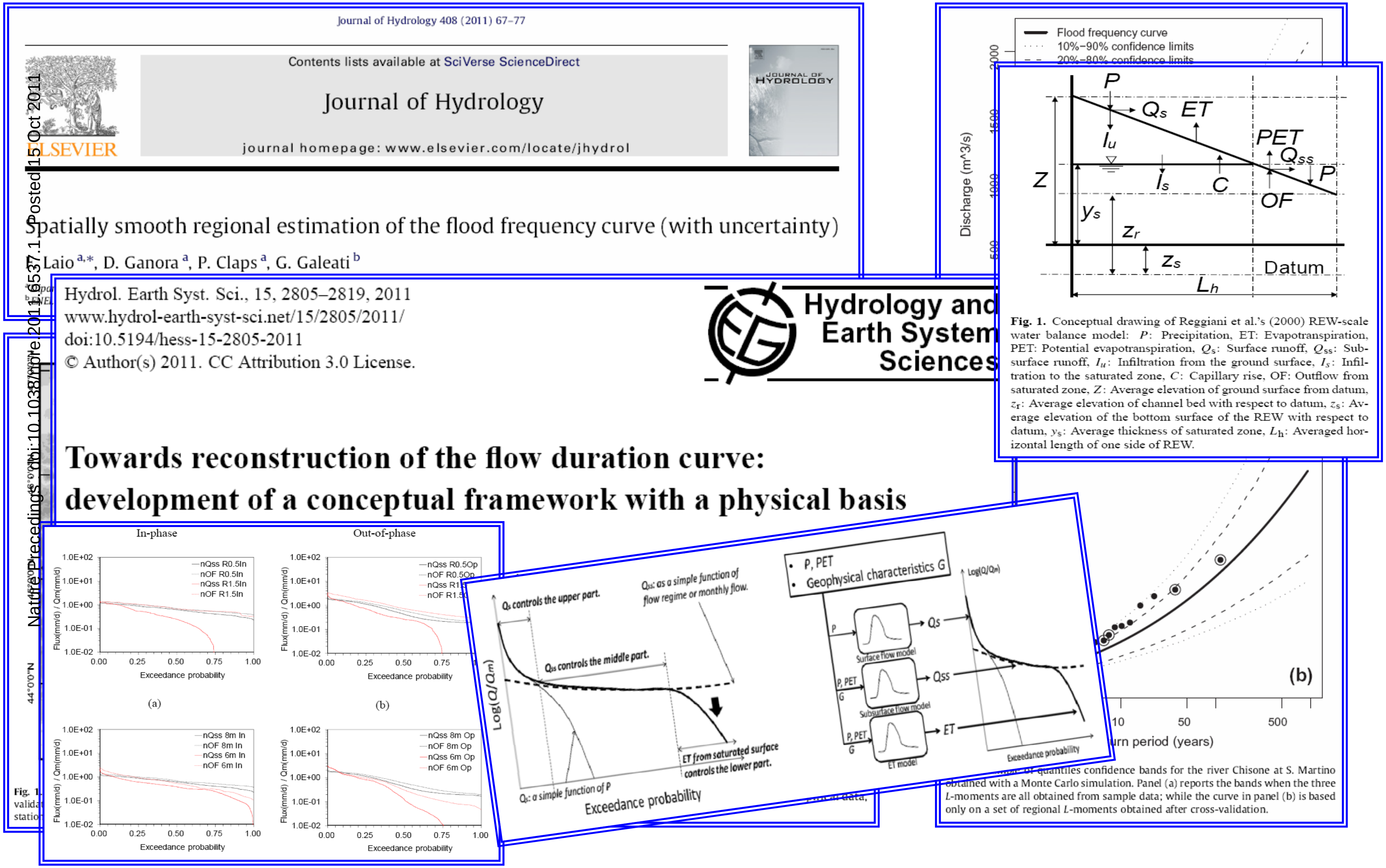
$Sg_2 = \{ g_{ji}, R_{ji} \}$,
where g_{Ji}- watershed in specific coordinates



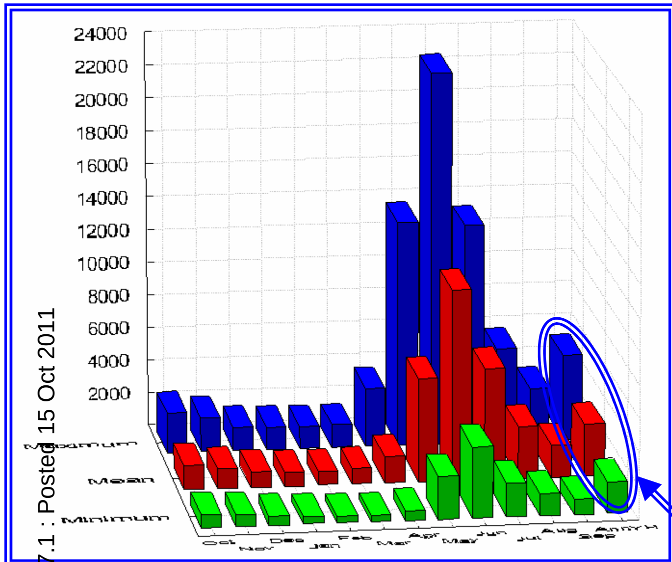
Math Models for the Analysis

Nature Precedings : doi:10.1038/npre.2011.6537.1 : Posted 15 Oct 2011

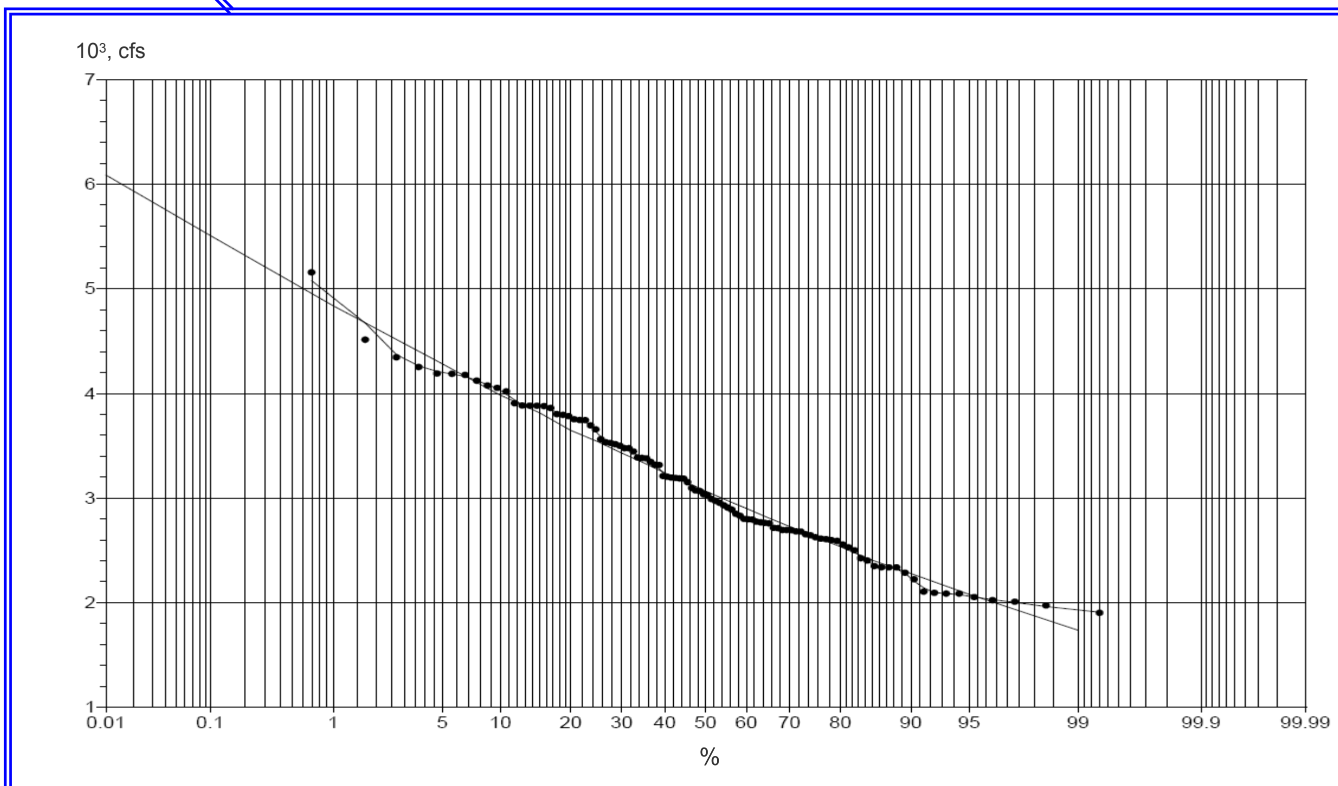
The Duration Curves



The Duration Curve

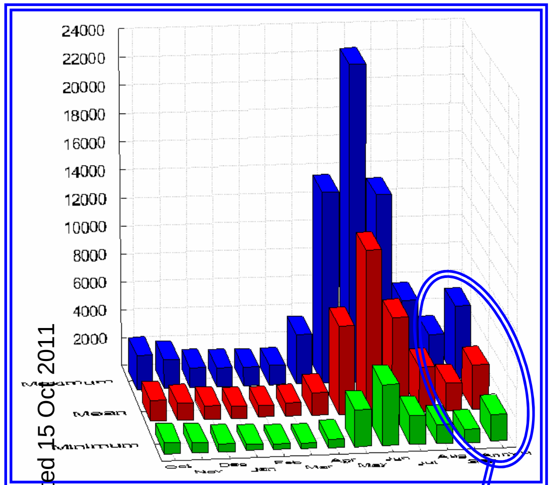


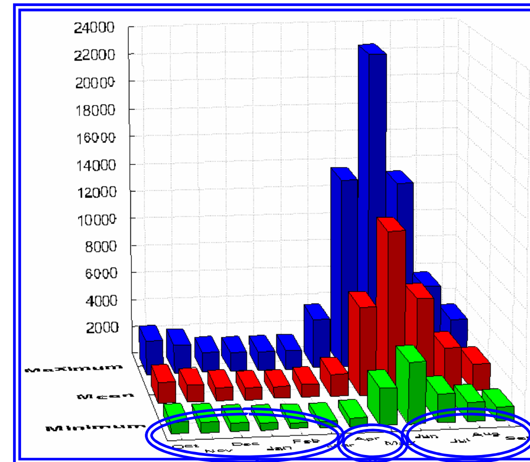
The hydrograph of hydrological year for USGS 06191500 1911-2010

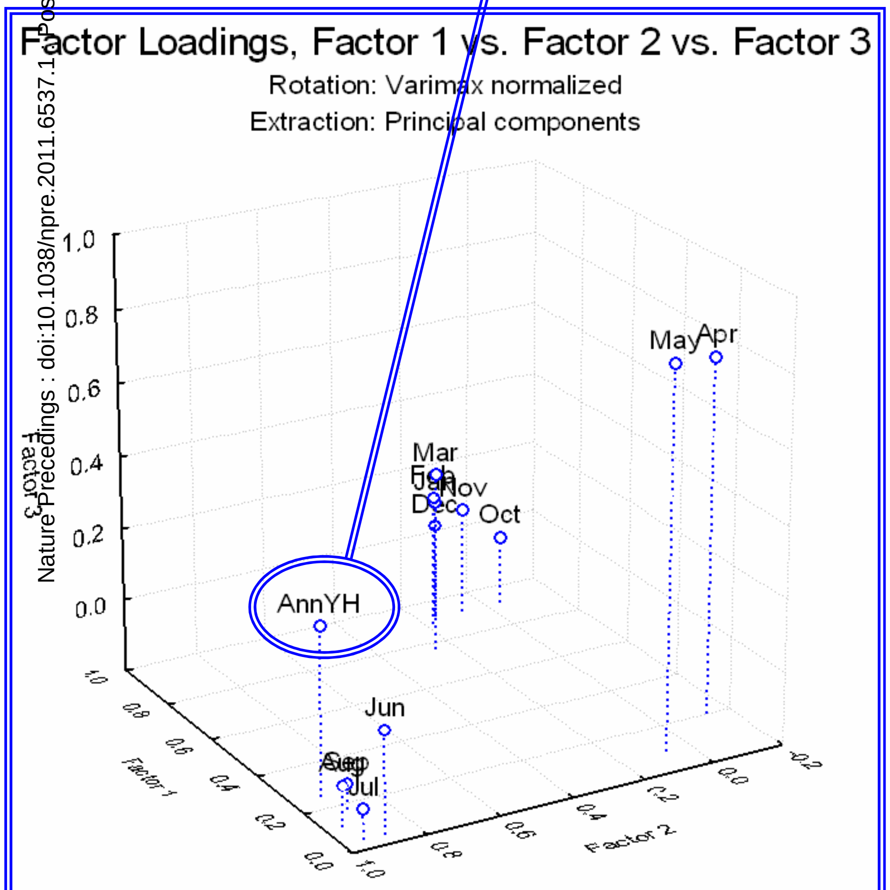


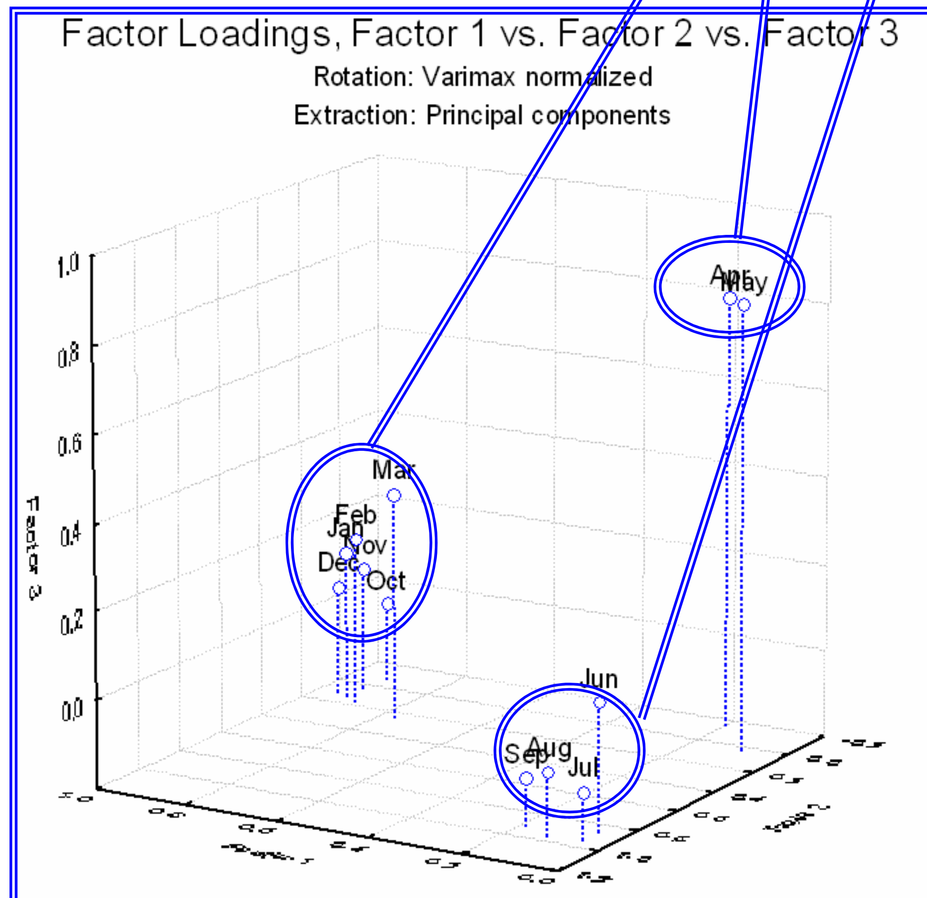
Empirical durational curve 1911-2010 for USGS 06191500 Yellowstone River at Corwin Springs, MT

Annual distribution

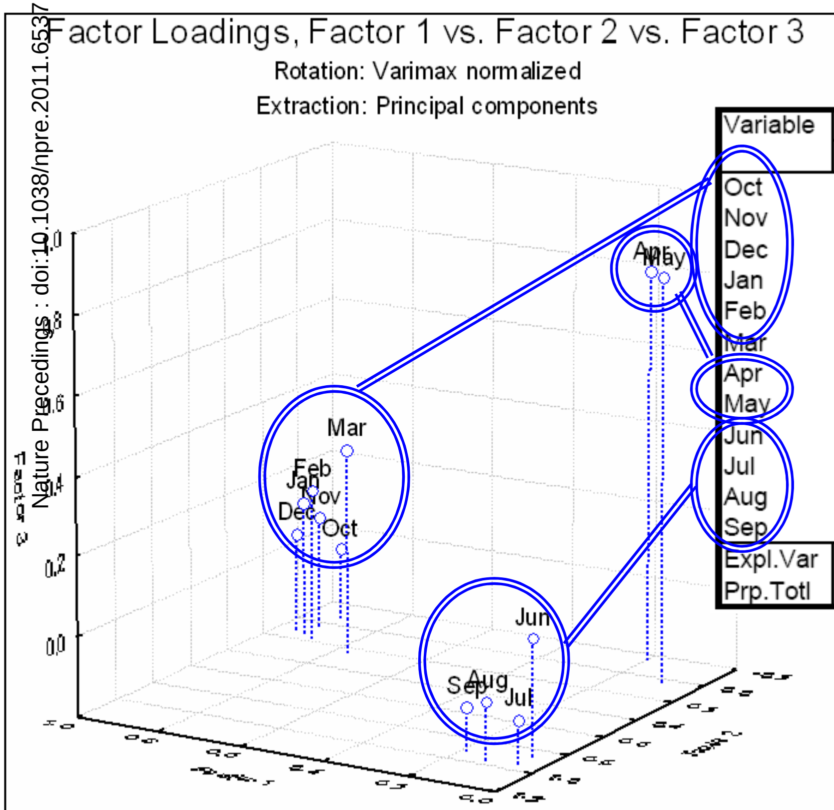


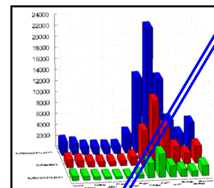






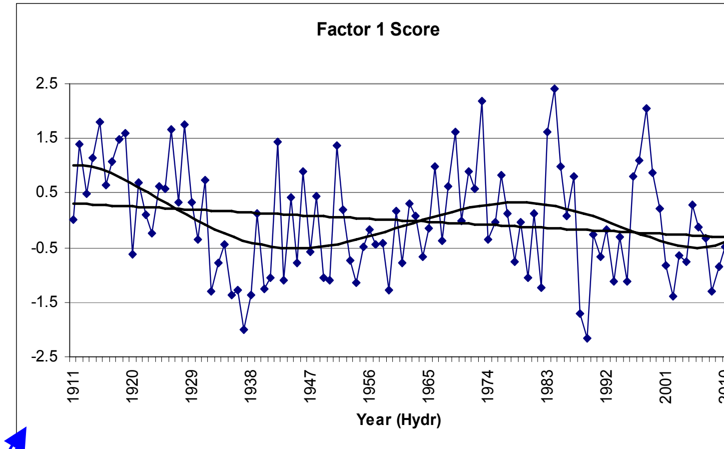
Structure of the seasonal variability

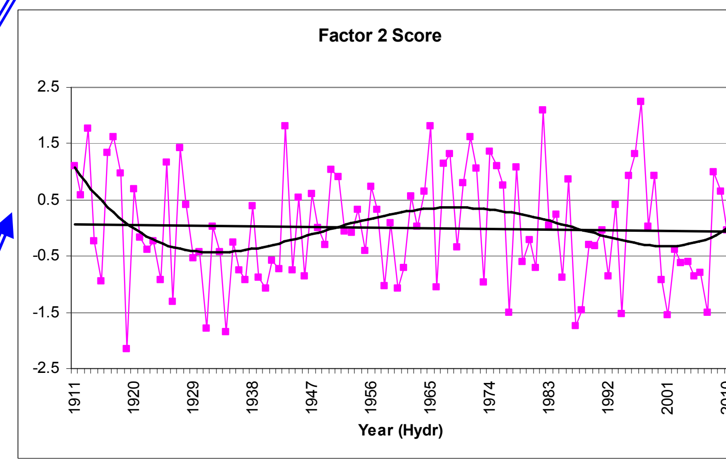


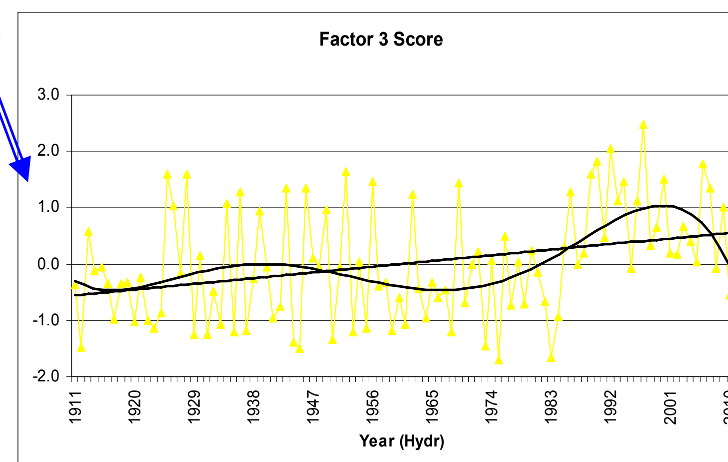


Variable	Factor Loadings		
	Fact 1	Fact 2	Fact 3
Oct	0.92		
Nov	0.92		
Dec	0.95		
Jan	0.92		
Feb	0.89		
Mar	0.77	0.25	0.32
Apr			0.79
May			0.82
Jun		0.87	
Jul		0.94	
Aug		0.96	
Sep		0.91	
Expl.Var	4.93	3.54	1.50
Prp.Totl	0.41	0.30	0.12

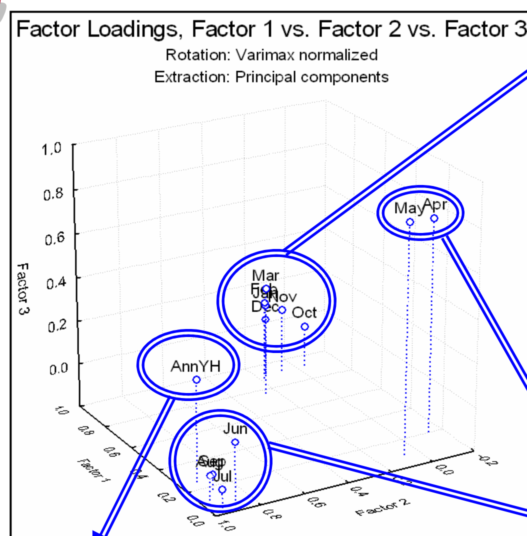
More that one dimension

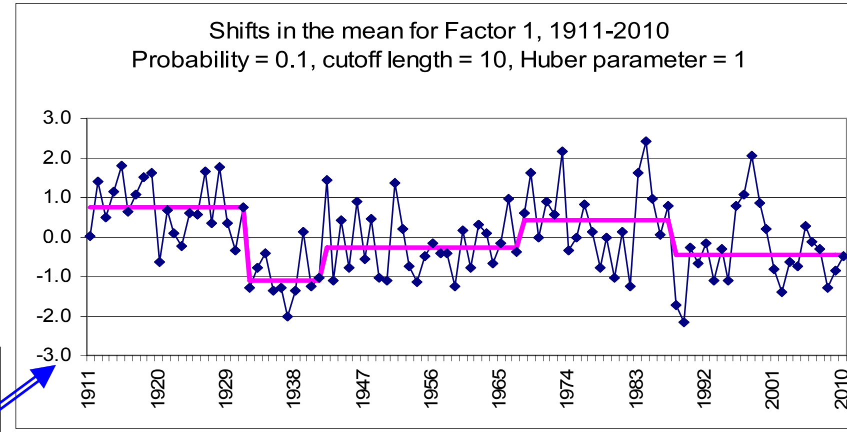


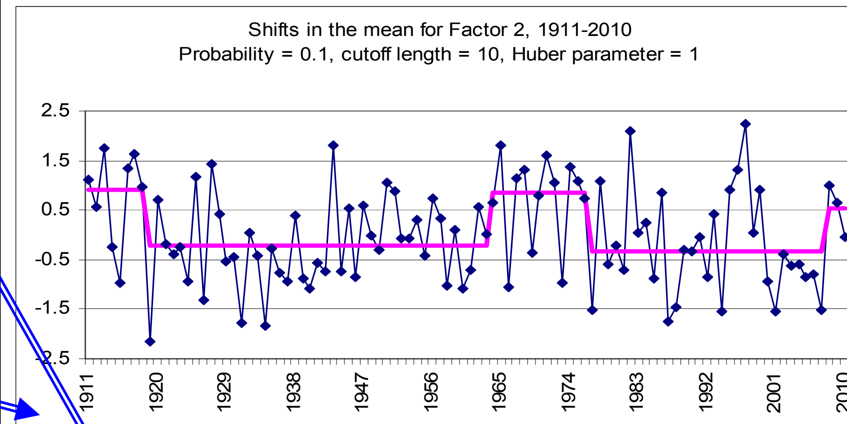


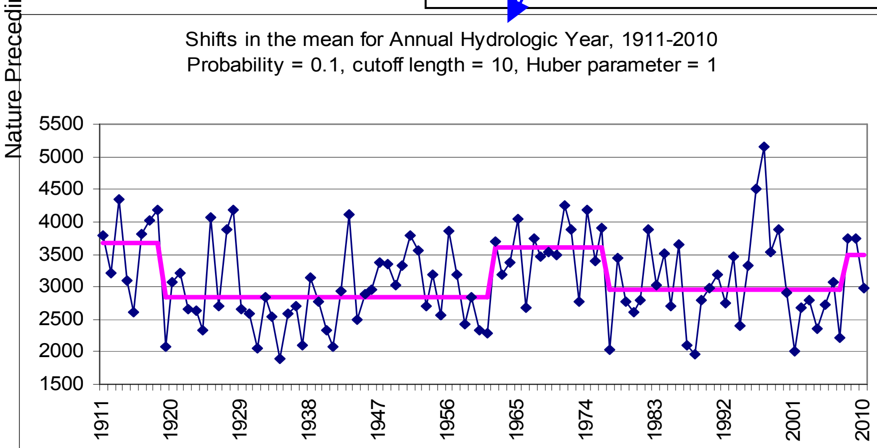


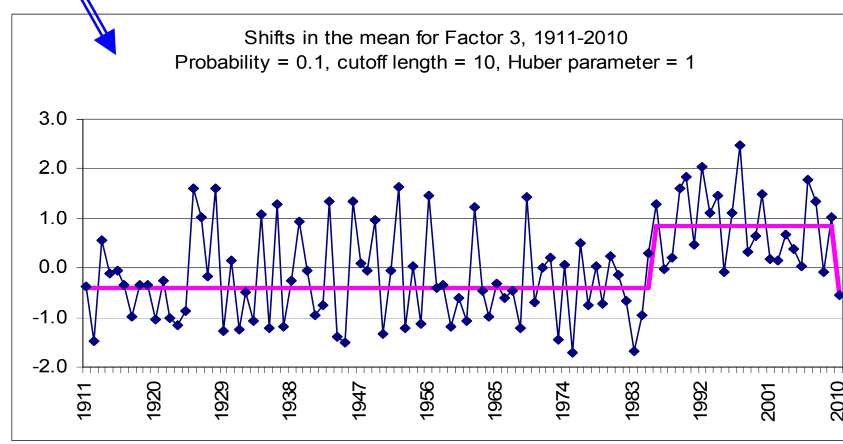
Interannual seasonal regime: shifts



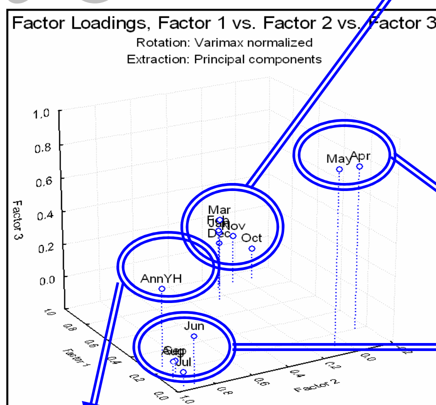


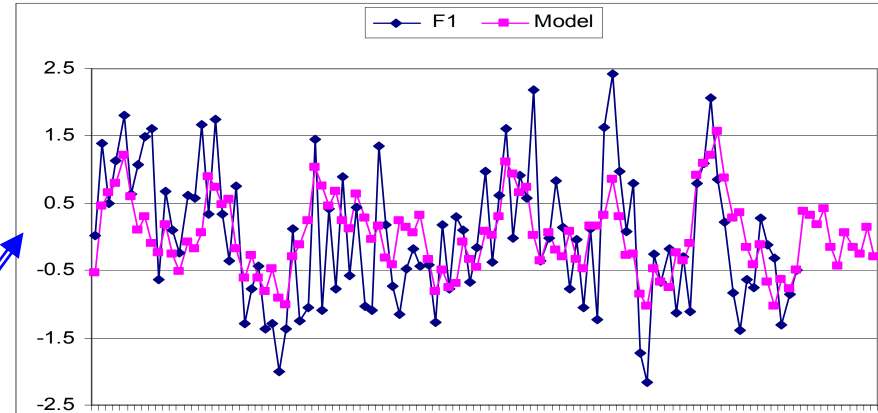


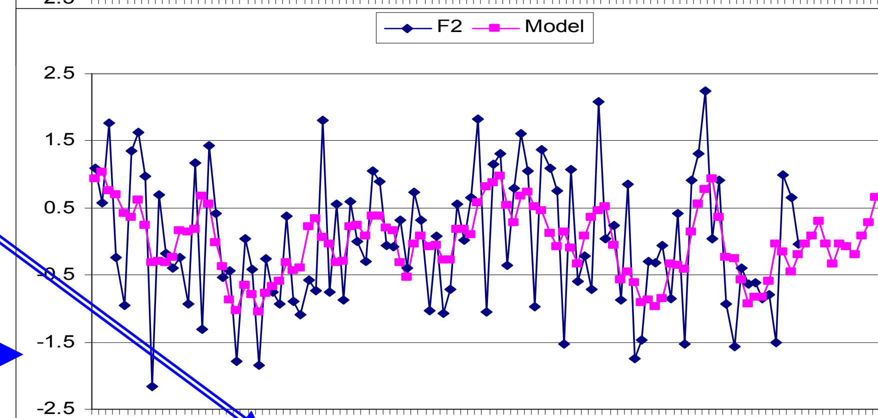


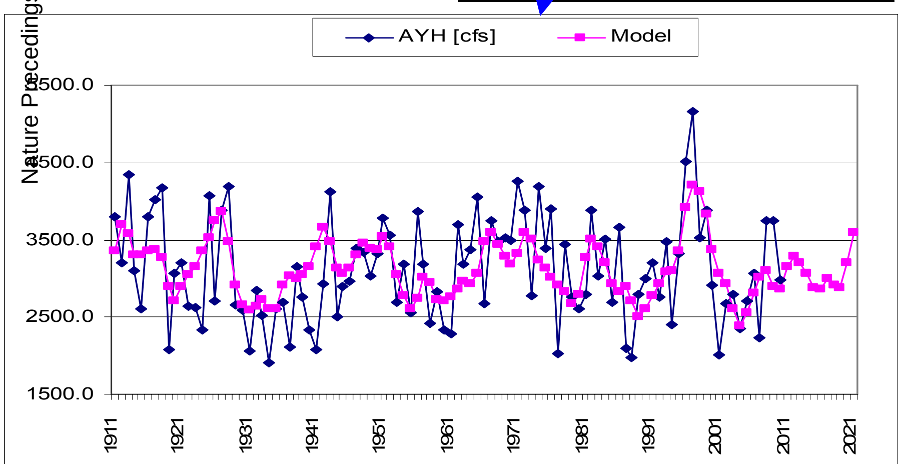


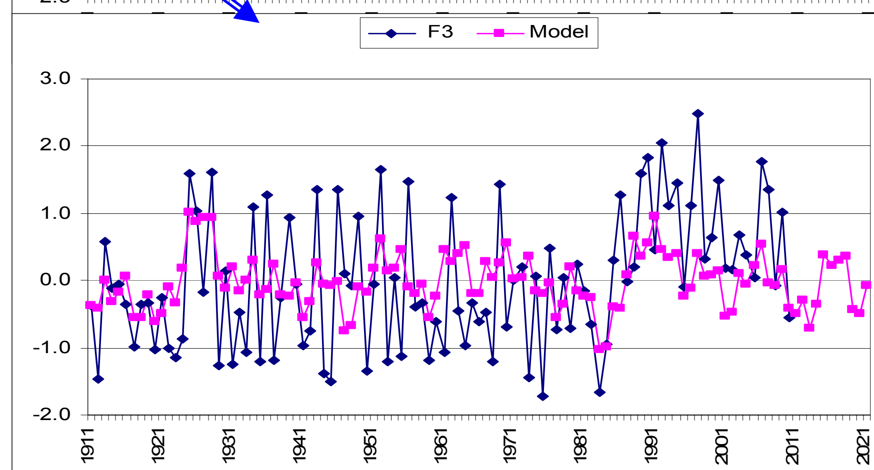
Modeling the Regimes 1911-2010 (2021)











The Wavelets

Global and Planetary Change 78 (2011) 1–13

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A synthesis of the time-scale v
continuous wavelet transform

A. Rossi *, N. Massei, B. Laignel

Journal of Hydrology 376 (2009) 295–306

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Journal of Hydrology

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A coupled approach of surface hydrological modelling and Wavelet Analysis for understanding the baseflow components of river discharge in karst environments

F. Salerno *, G. Tartari

Water Research Institute, National Research Council (IRSA-CNR), Località Occhiate, 20047, Brugherio, Milan, Italy

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Journal of Hydrology

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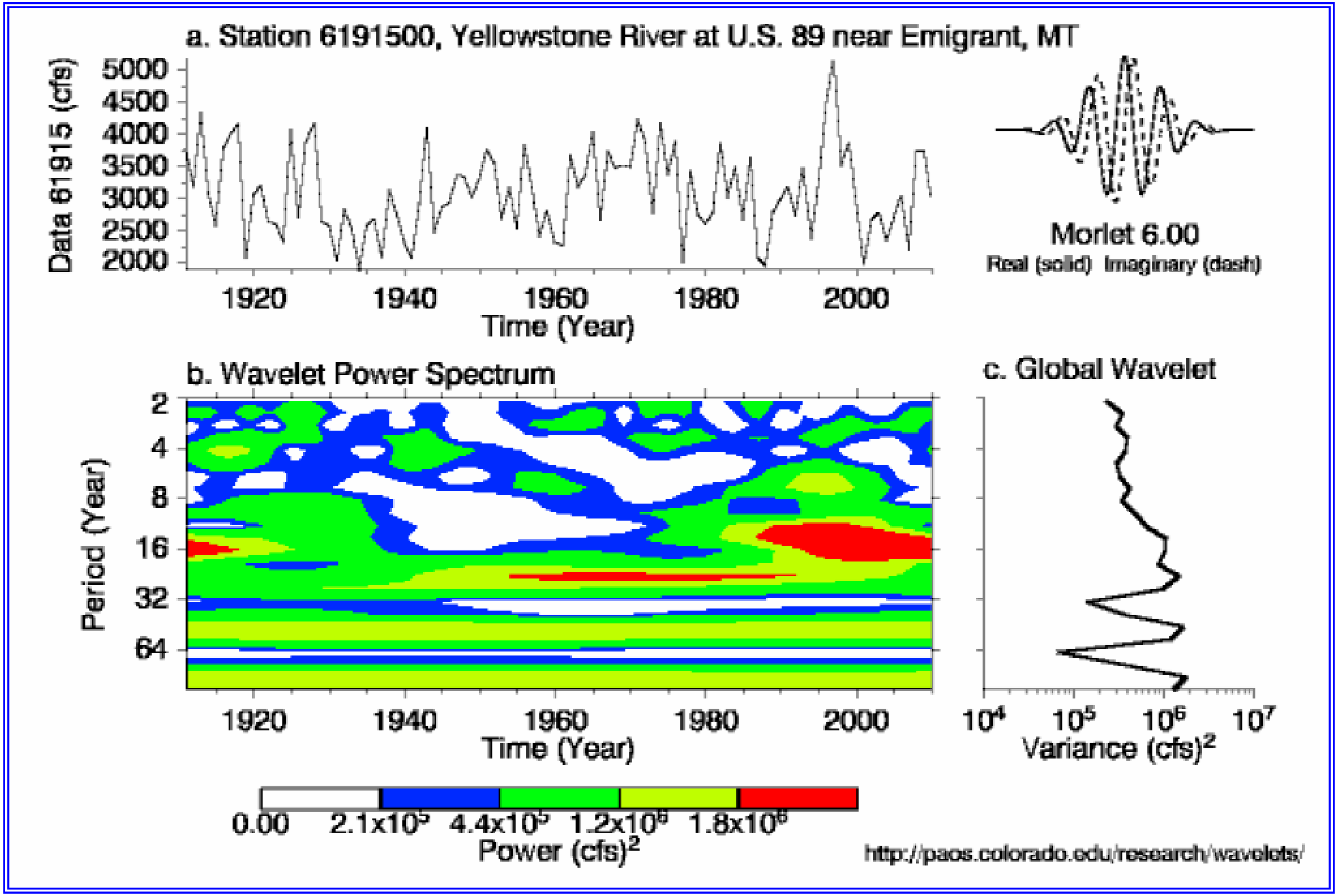
A wavelet-support vector machine conjunction model for monthly streamflow forecasting

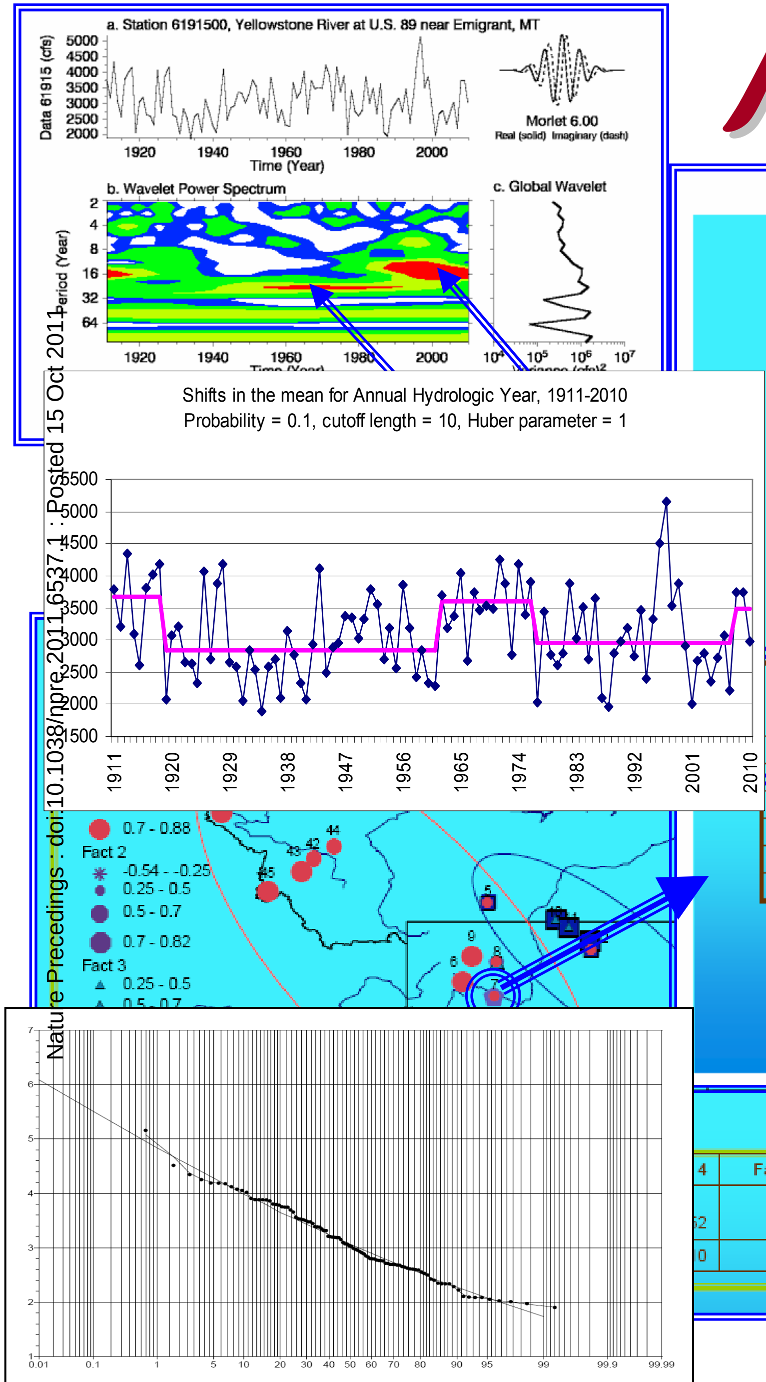
Ozgur Kisi [a,*], Mesut Cimen [b]

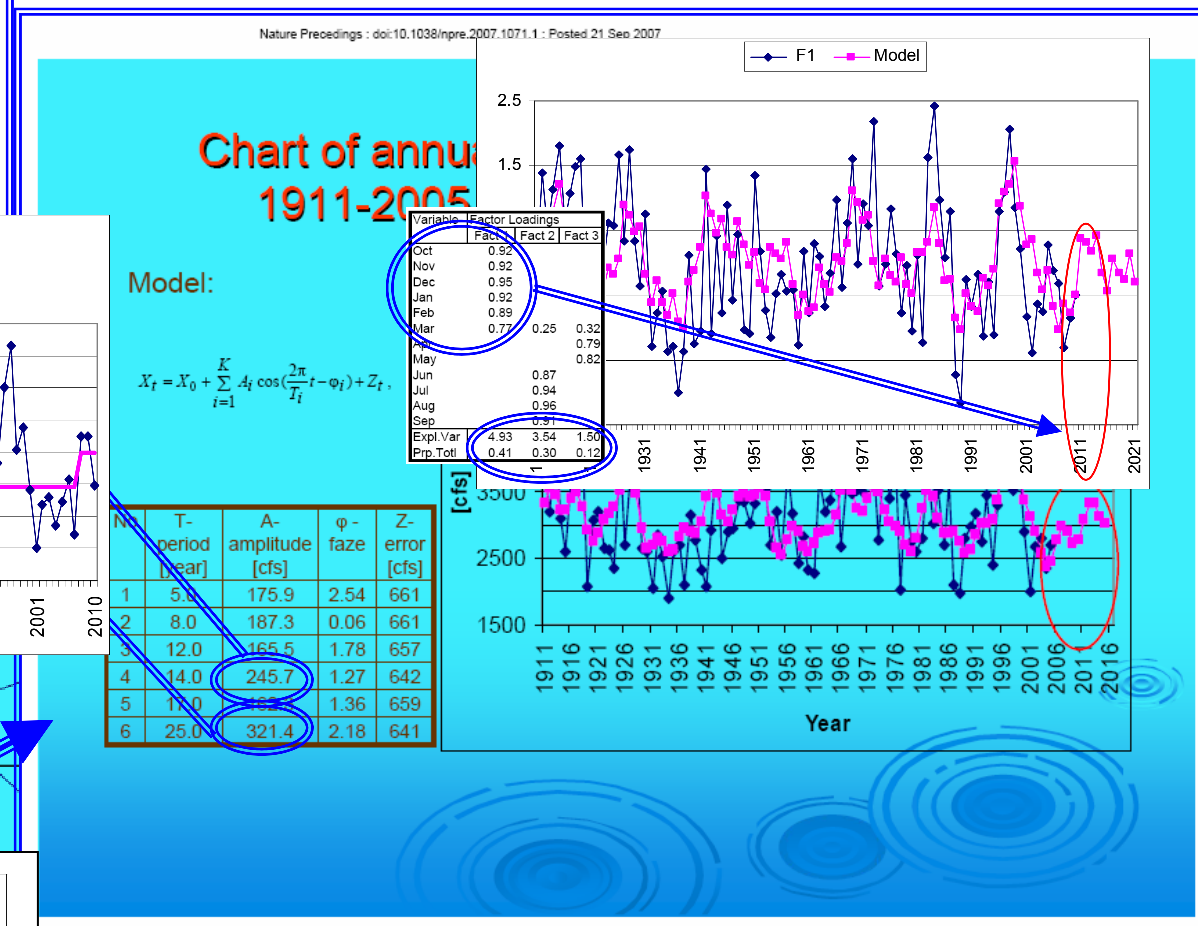
[a] *Erciyes University, Engineering Faculty, Civil Eng. Dept., Hydraulics Division, 38039 Kayseri, Turkey*
[b] *Suleyman Demirel University, Engineering-Architecture Faculty, Civil Eng. Dept., Isparta, Turkey*

The Wavelets

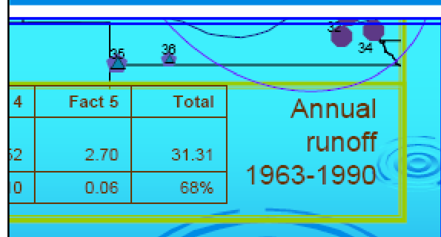


Math Models & Time Variability





No	T-period [year]	A-amplitude [cfs]	φ - faze	Z-error [cfs]
1	5.0	175.9	2.54	661
2	8.0	187.3	0.06	661
3	12.0	165.5	1.78	657
4	14.0	245.7	1.27	642
5	17.0	[illegible]	1.36	659
6	25.0	321.4	2.18	641



The Knowledge of Variability for Watershed

* The Knowledge about watershed comes only from the analysis of the empirical data (instrumental observations)

* Variability has to be defined as annual & seasonal structure in coordinates of the hydrologic time & space for particular watershed (coordinates have nonstationary axes, the factor's axes for multidimensional process are considered as the basis for coordinate system)

* The math model does not have criteria to verify itself (Gödel's incompleteness theorems) & multi models & scales studies with use of empirical data have to be completed

Communicating the Knowledge

The Uncertainty in Hydrology: the Usual Approach

Climatic Change (2011) 105:387–408
DOI 10.1007/s10584-010-9896-4

The role of uncertainties in the design of international water treaties: an historical perspective

Alena Drieschova · Itay Fischhendler · Mark Giordano

Table 1 Uncertainty language in transboundary water agreements, 1900–2007

Nature of uncertainty	% of sample which mentioned
Exogenous resource uncertainty	
Flow variability	49%
General environmental	13%
Scientific	4%
Explicit climate change uncertainty	0.69%
Exogenous background [illegible]	
International relations	[illegible]
Demand uncertainty	[illegible]
Induced endogenous unc[illegible]	
Treaty implementation	[illegible]
Data	[illegible]
Treaty finance	[illegible]
Treaty effectiveness	[illegible]
Treaty created infrastr[illegible]	[illegible]

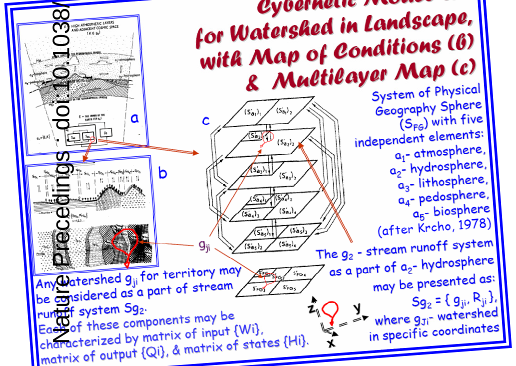
Table 2 Changes in types of uncertainty mentioned in transboundary water agreements, 1900–2007

	1900–1949	1950–1969	1970–1989	1990–2007
Exogenous resource uncertainties				
Flow variability	44%	56%	41%	51%
General environmental uncertainty	2%	6%	19%	24%
Scientific uncertainty	4%	1%	6%	6%
Explicit climate change uncertainty	0%	0%	0%	3%
Exogenous background uncertainties				
International relations	17%	4%	7%	4%
Induced endogenous uncertainties				
Implementation uncertainty	6%	7%	6%	7%
Data uncertainty	2%	0%	0%	1%
Financial uncertainty	6%	6%	7%	4%
Effectiveness uncertainty	4%	1%	7%	4%
Infrastructural uncertainty	10%	13%	15%	28%

The Uncertainty & The Knowledge through Modeling: Object, Data, Analysis & Results

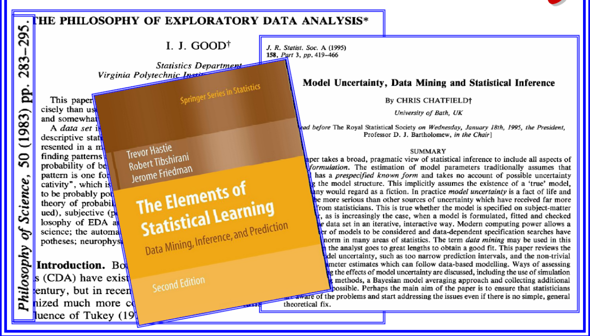
The knowledge (K)= 0, about a new object for the consideration
the uncertainty (U)= 1

Cybernetic Model (a) for Watershed in Landscape, with Map of Conditions (b) & Multilayer Map (c)



K_p = 1 & we have the direction for the research, the task, U = 0, but the Knowledge is previous (K_p)

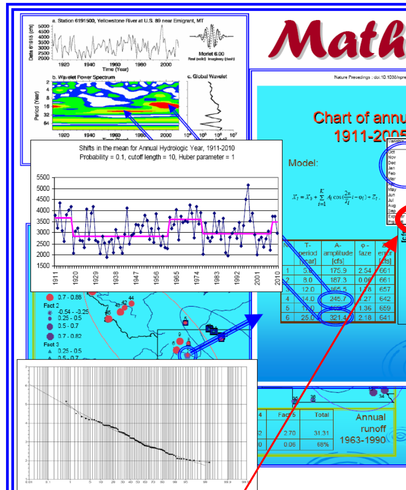
From Data Analysis to Statistical Learning



The Statistical Learning is the way to obtain ("extract") the structure of a natural object

The conceptual model (Cybernetic Model) is the way to use previously obtained Knowledge

Math Models & Time Variability



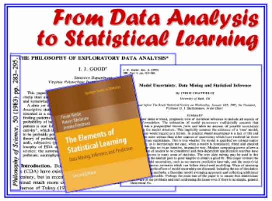
After Statistical Learning K > U

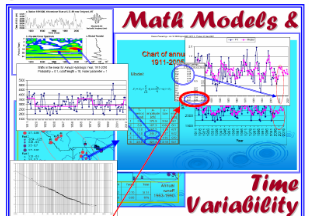
The Uncertainty from Analysis obtained for every model.
For Factor Analysis
U=1- explained variability

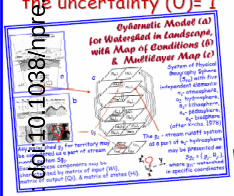
Communicating the Knowledge for the Watershed

The Uncertainty & The Knowledge through Modeling: Object, Data, Analysis & Results

The knowledge (K)= 0, about a new object for the consideration the uncertainty (U)= 1







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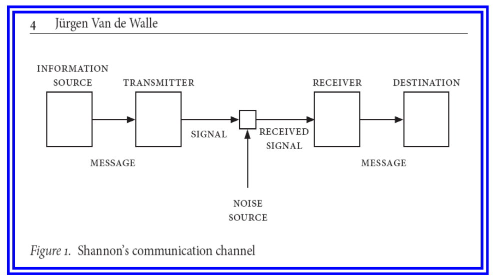
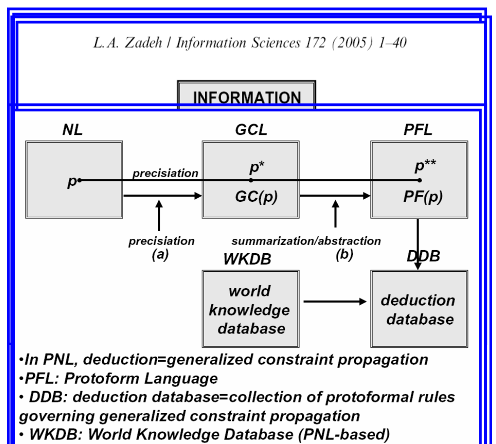
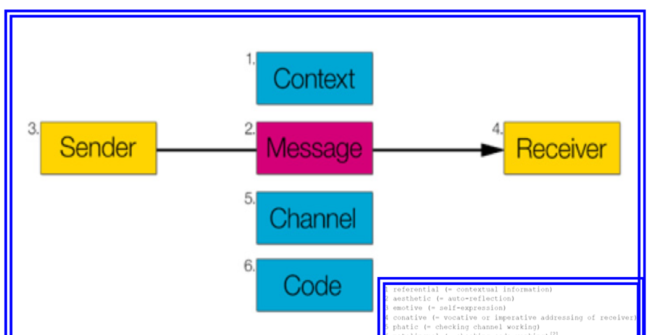
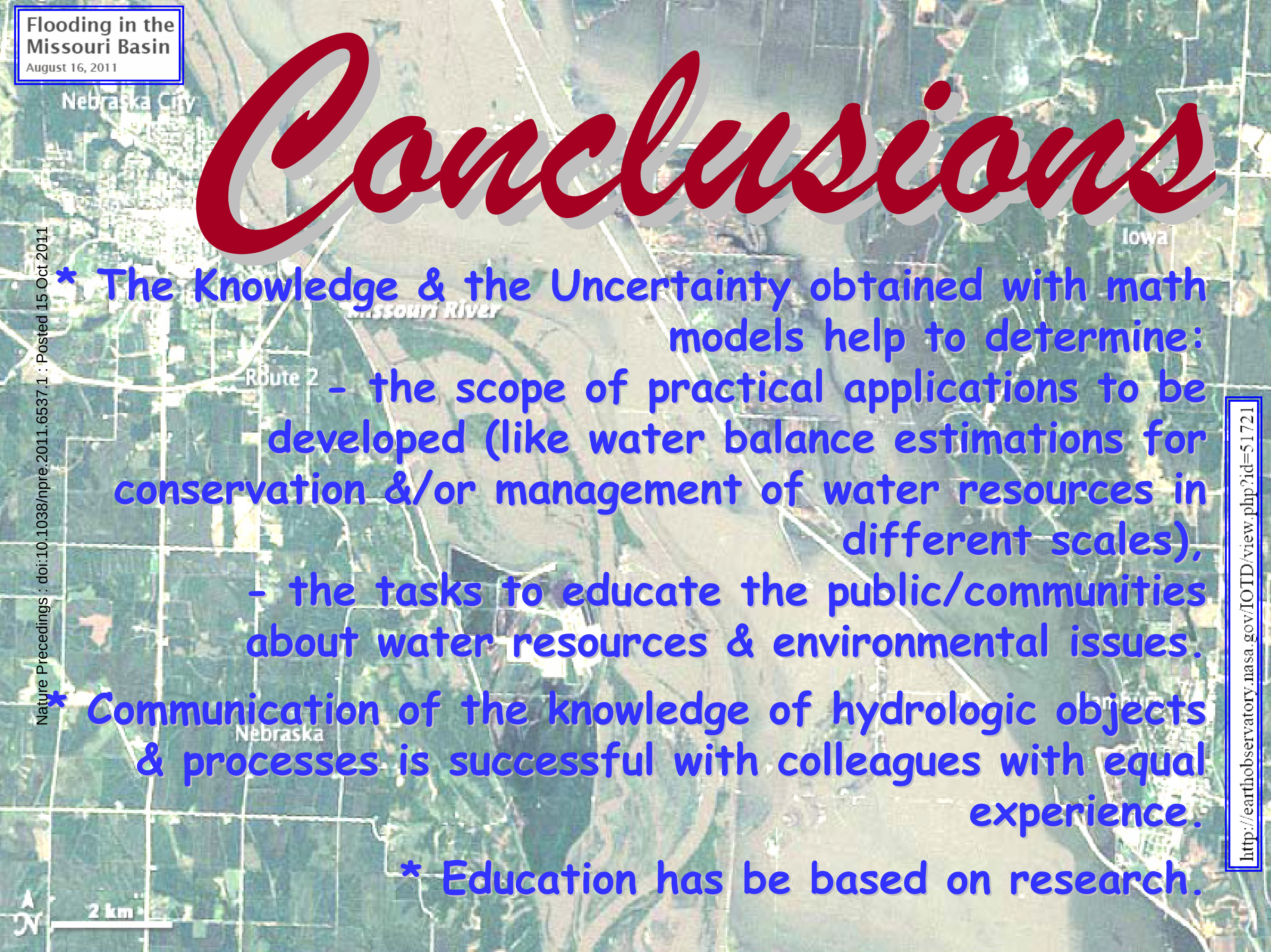


Figure 1. Shannon's communication channel





Scientist working in Hydrology have to handle the Uncertainty & communicate the Knowledge about time-spatial variability of the Watershed characteristics



Conclusions

* The Knowledge & the Uncertainty obtained with math models help to determine:
  - the scope of practical applications to be developed (like water balance estimations for conservation &/or management of water resources in different scales),
  - the tasks to educate the public/communities about water resources & environmental issues.
* Communication of the knowledge of hydrologic objects & processes is successful with colleagues with equal experience.
* Education has be based on research.