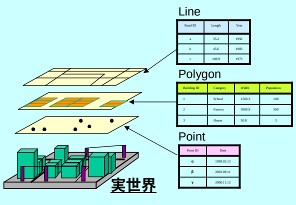
建設技術におけるGISの高度利用

２００６．７．２８

九州大学　環境システム科学研究センター
江崎　哲郎

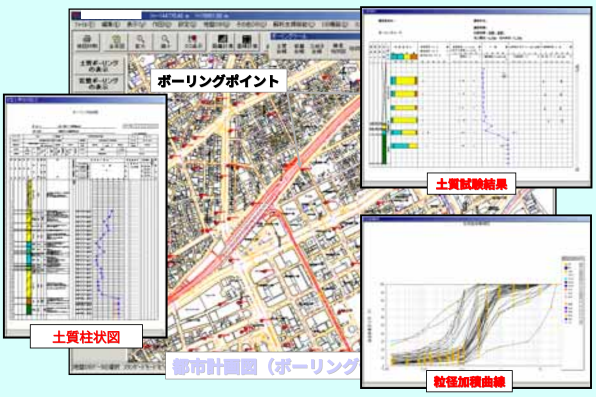
地理情報システム (GIS) とは



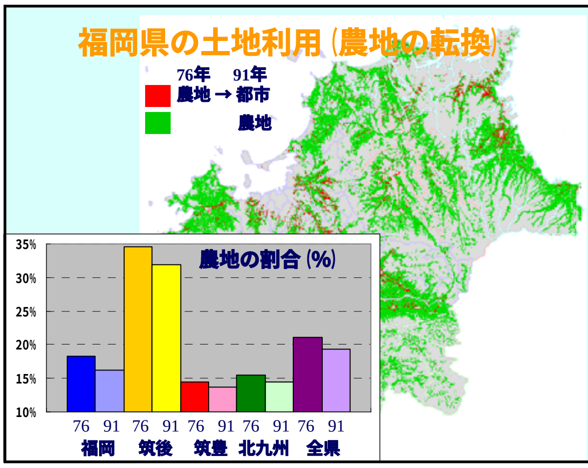
実世界をポイント，ライン，ポリゴン等によってデータモデル化し，各種情報を地図上で統合する．

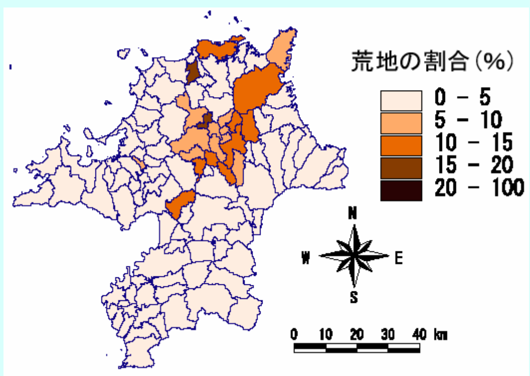
GISは各種地理情報を統合･分析･表示するシステムであり，業務の効率化，迅速化および意思決定などを支援するツールである．

現在GISは様々な分野で導入･システム構築が図られているが････．



福岡県の土地利用 (農地の転換)





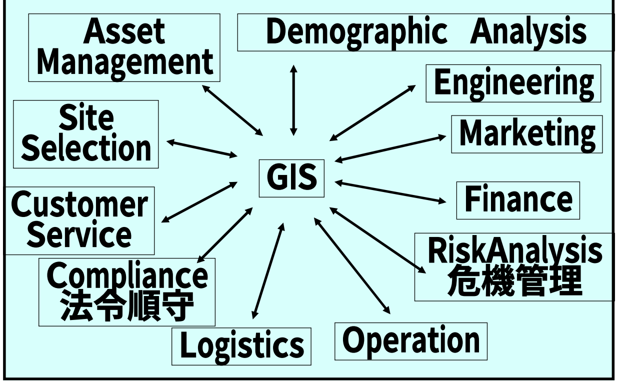
- GIS関係省庁連絡会議，13省庁，
  GISアクションプログラム2002-2005，
  GISを利用する基盤環境の整備
  GISによる豊かな国民生活の実現
  電子政府･電子自治体の推進
- 測位･地理情報システム等推進会議の設置
  ２００５．９．１２　内閣官房の所管，4省庁の協力
  １４省庁参加
- 法整備 (地理空間情報活用推進基本法案)，
- 次期アクションプログラム (2006-2009)

GISの定義

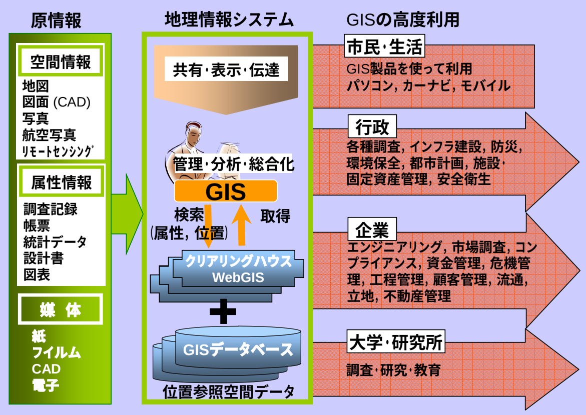
① 空間データ（地図）と非空間データ（帳票，統計資料）を**統合**し、空間的な**検索，解析，表示**を行う
――DATA 志向

② 新しい社会基盤として、安心･安全などの問題解決のための先進的な能力を専門家に付与する**意思決定支援**システム　――TASK志向

米企業におけるGISの展開



GISによる各種情報の高度利用体制



GISを利活用する目的

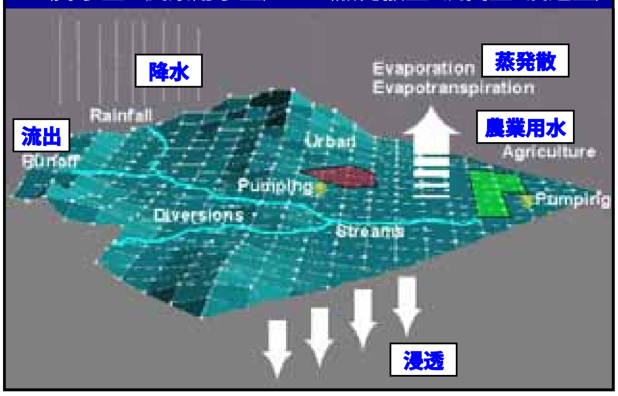
- 通常の仕事の効率化･コスト削減
  Do what we currently do more efficiently.
- 通常では出来ないことの実現
  Do things that we cannot currently do.
- データの分散共有と統合
  Allow efficient data sharing and integrity
- 将来のニーズに備える
  Anticipate future needs

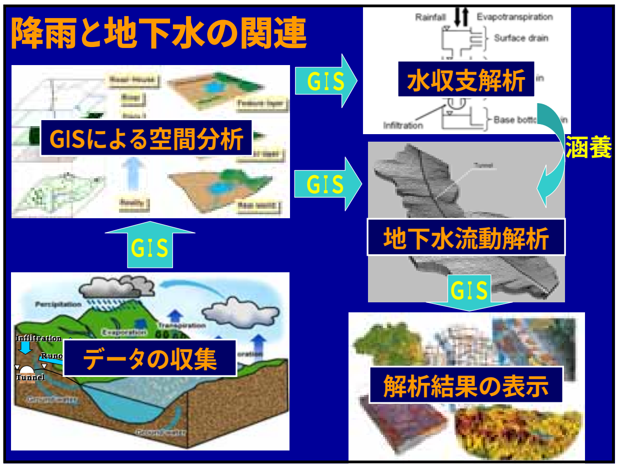
GISを用いた広域水循環時空解析システムの構築

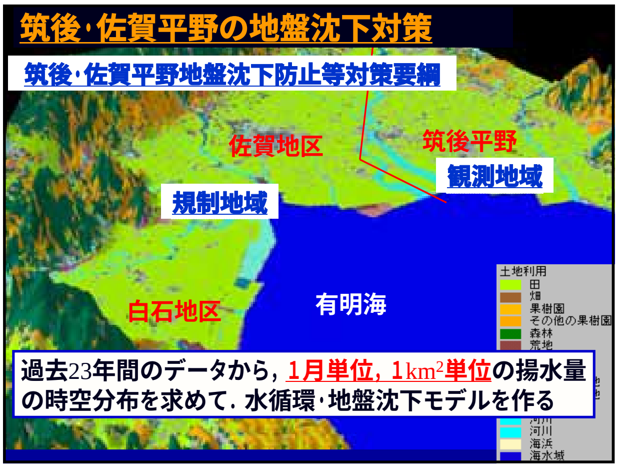
九州大学大学院　工学研究院
環境システム科学研究センター
江崎哲郎，三谷泰浩，池見洋明，川内一徳

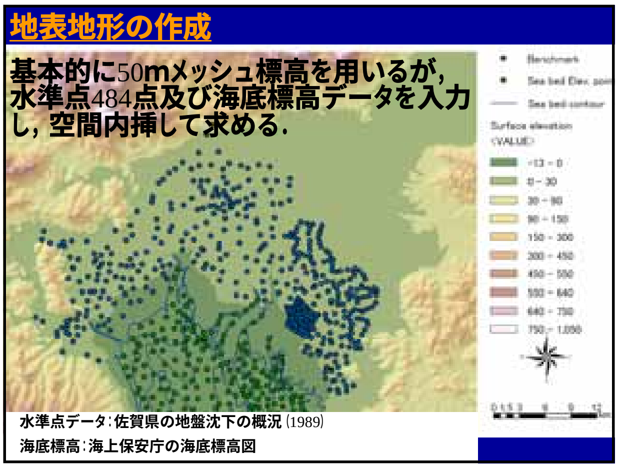
水収支解析

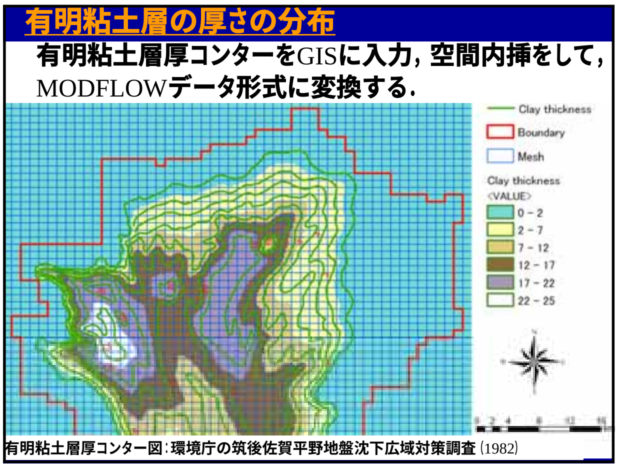
Σ（降水量 +農業用水量）＝Σ（蒸発散量+流出量+浸透量）

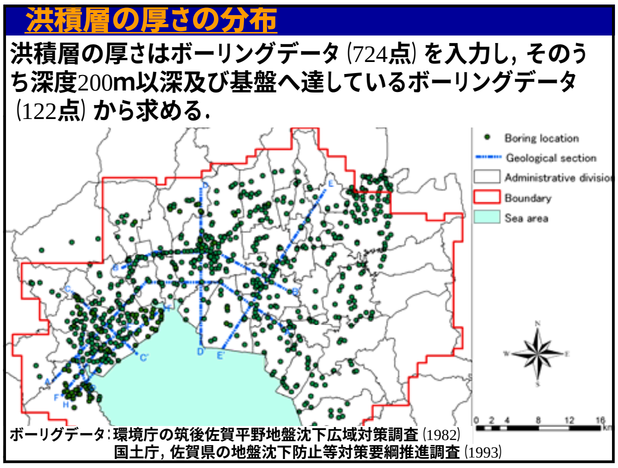


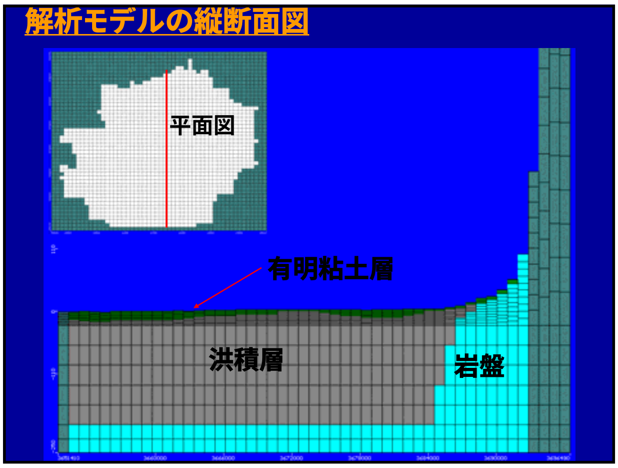

降雨と地下水の関連
Rainfall
Evapotranspiration
Surface drain
Infiltration
GISによる空間分析
GIS
水収支解析
涵養
GIS
地下水流動解析
GIS
データの収集
GIS
解析結果の表示

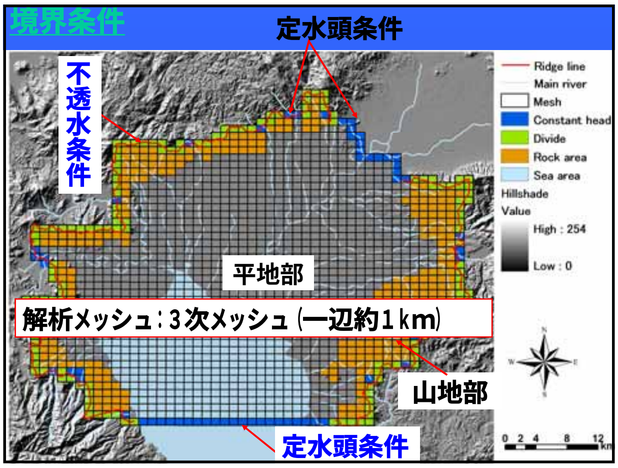

筑後・佐賀平野の地盤沈下対策
筑後・佐賀平野地盤沈下防止等対策要綱
佐賀地区
筑後平野
観測地域
規制地域
白石地区
有明海
土地利用
田
畑
果樹園
その他の果樹園
森林
荒地
河川
海浜
海水域
過去23年間のデータから，1月単位，1km²単位の揚水量の時空分布を求めて．水循環・地盤沈下モデルを作る

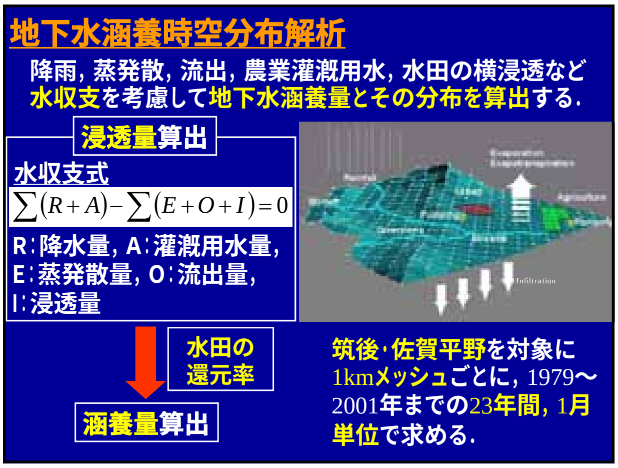

地表地形の作成
基本的に50mメッシュ標高を用いるが，水準点484点及び海底標高データを入力し，空間内挿して求める．
Benchmark
Sea bed Elev. point
Sea bed contour
Surface elevation
<VALUE>
水準点データ：佐賀県の地盤沈下の概況（1989）
海底標高：海上保安庁の海底標高図

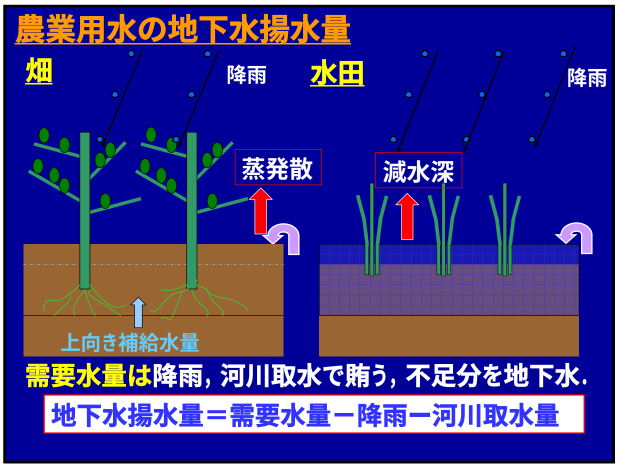

有明粘土層の厚さの分布
有明粘土層厚コンターをGISに入力，空間内挿をして，MODFLOWデータ形式に変換する．
Clay thickness
Boundary
Mesh
Clay thickness
<VALUE>
0 - 2
2 - 7
7 - 12
12 - 17
17 - 22
22 - 25
有明粘土層厚コンター図：環境庁の筑後佐賀平野地盤沈下広域対策調査（1982）

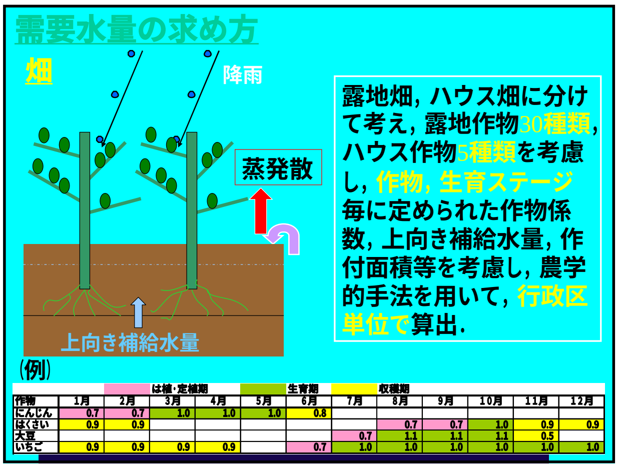

洪積層の厚さの分布
洪積層の厚さはボーリングデータ（724点）を入力し，そのうち深度200m以深及び基盤へ達しているボーリングデータ（122点）から求める．
Boring location
Geological section
Administrative division
Boundary
Sea area
ボーリグデータ：環境庁の筑後佐賀平野地盤沈下広域対策調査（1982）
国土庁，佐賀県の地盤沈下防止等対策要綱推進調査（1993）


解析モデルの縦断面図
平面図
有明粘土層
洪積層
岩盤

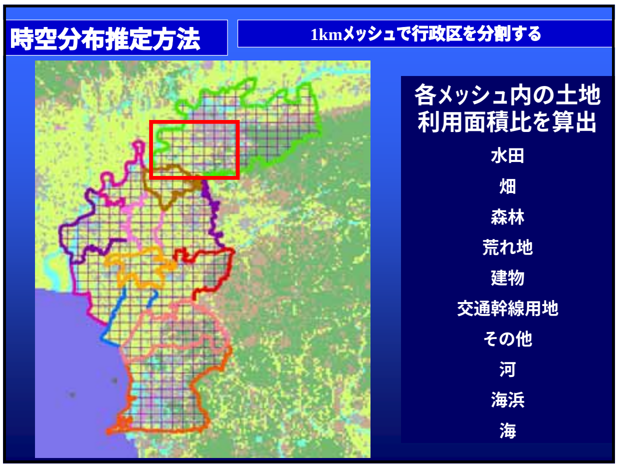


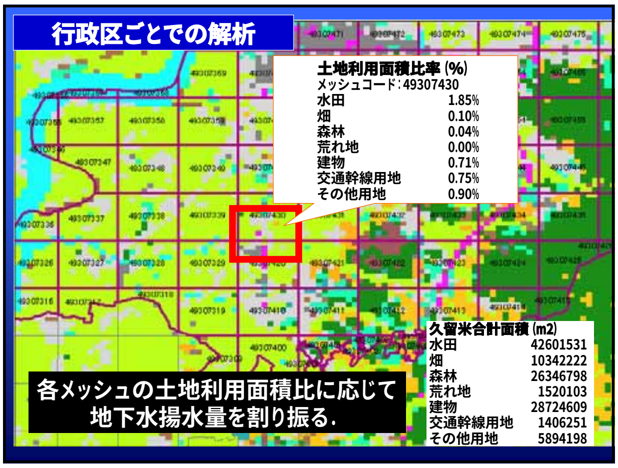


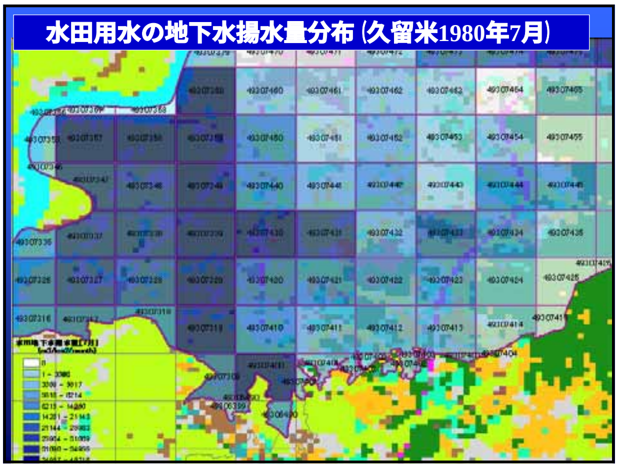


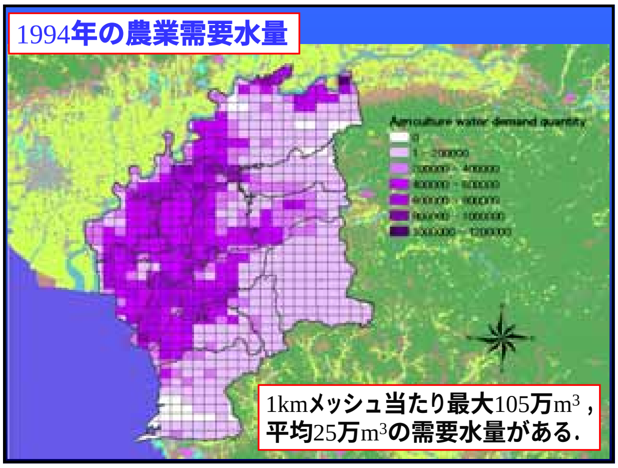


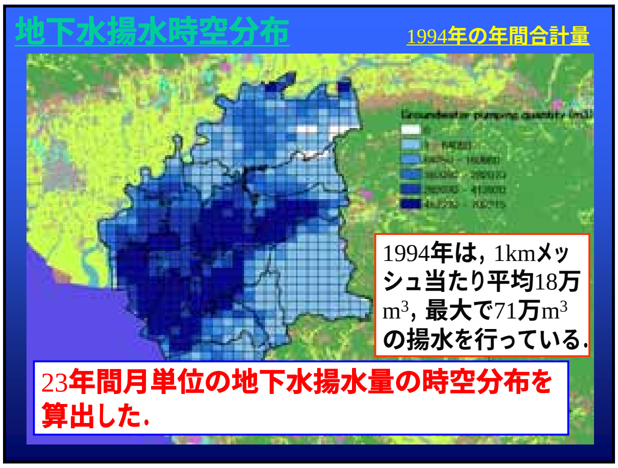
作物	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月
にんじん	0.7	0.7	1.0	1.0	1.0	0.8						
はくさい	0.9	0.9						0.7	0.7	1.0	0.9	0.9
大豆							0.7	1.1	1.1	1.1	0.5	
いちご	0.9	0.9	0.9	0.9		0.7	1.0	1.0	1.0	1.0	1.0	1.0

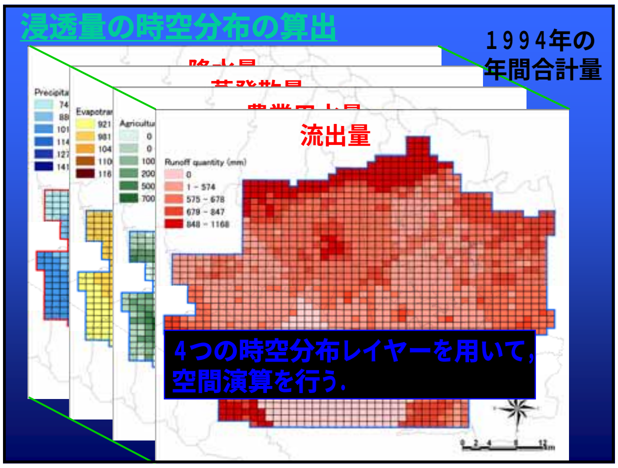


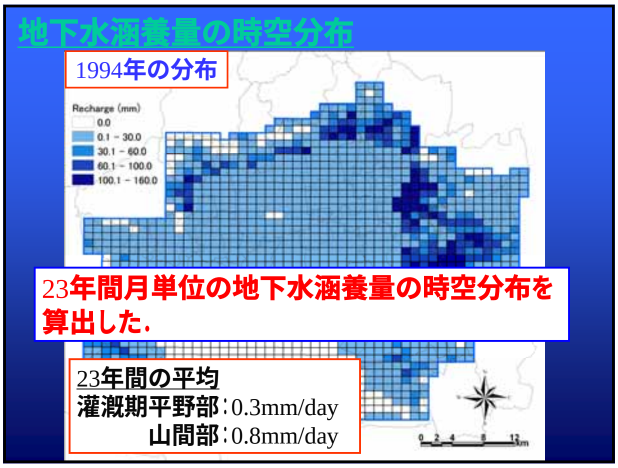


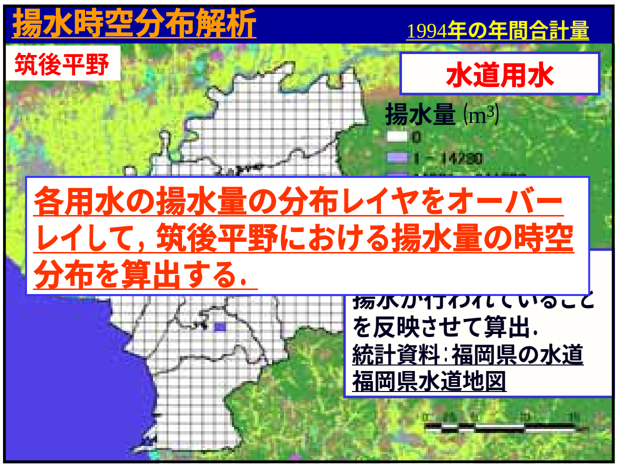

水田用水の地下水揚水量分布（久留米1980年7月）


1994年の農業需要水量
Agriculture water demand quantity
1kmメッシュ当たり最大105万m3，
平均25万m3の需要水量がある．

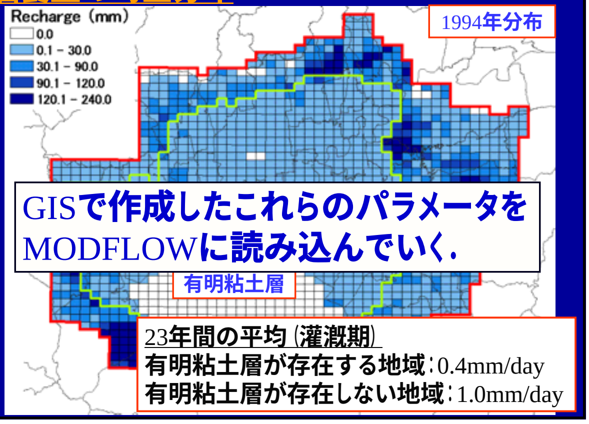

地下水揚水時空分布
1994年の年間合計量
1994年は，1kmメッシュ当たり平均18万m3，最大で71万m3の揚水を行っている．
23年間月単位の地下水揚水量の時空分布を算出した．


浸透量の時空分布の算出
1994年の
年間合計量
流出量
Runoff quantity (mm)
0
1 - 574
575 - 678
679 - 847
848 - 1168
4つの時空分布レイヤーを用いて，
空間演算を行う．


地下水涵養量の時空分布
1994年の分布
Recharge (mm)
0.0
0.1 - 30.0
30.1 - 60.0
60.1 - 100.0
100.1 - 160.0
23年間月単位の地下水涵養量の時空分布を算出した．
23年間の平均
灌漑期平野部：0.3mm/day
山間部：0.8mm/day

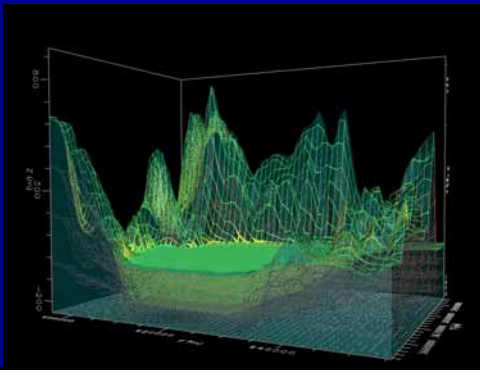

揚水時空分布解析
1994年の年間合計量
筑後平野
水道用水
揚水量（m3）
0
1 - 14280
各用水の揚水量の分布レイヤをオーバーレイして，筑後平野における揚水量の時空分布を算出する．
を反映させて算出．
統計資料：福岡県の水道
福岡県水道地図

涵養量の時空分布



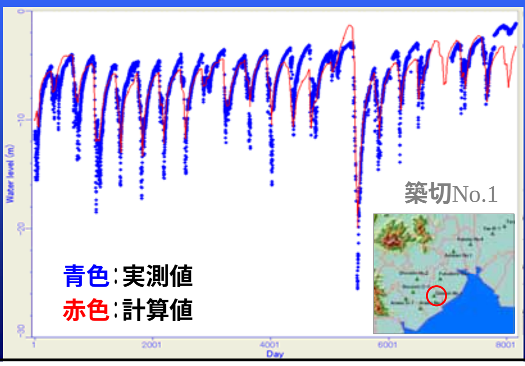
3次元地下水流動解析モデル

解析は1979年9月から2001年12月まで，
5日ステップで行う.



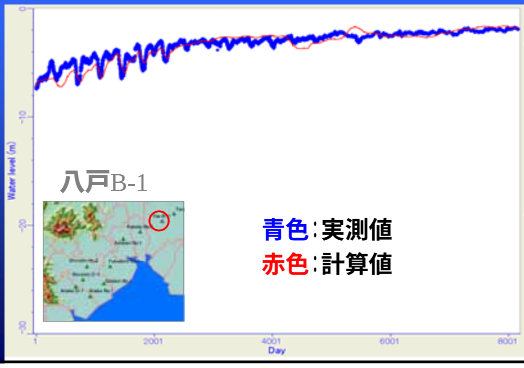
地下水位の計算値と実測値の比較

夏に地下水位が低下し，冬に上昇する季節的な変動や，
1994年の渇水時の地下水の低下の様子を再現できた.

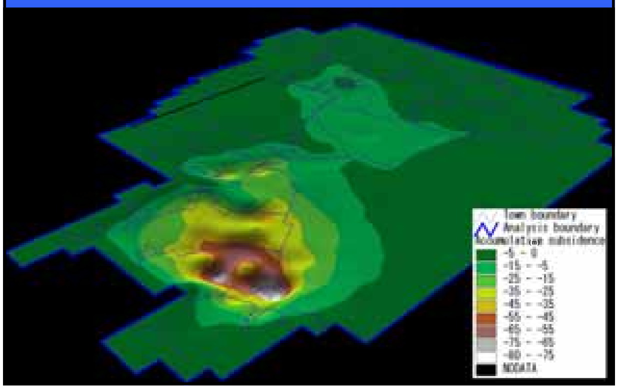


地下水位の計算値と実測値の比較

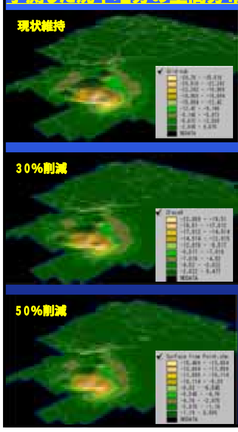
佐賀地区の揚水量削減により，水位が上昇し，変動
幅も小さくなっている様子を再現できた.



1979～1997年の１８年間の累計地盤沈下分布(3D)



予測した沈下増分の空間分布



2012年における沈下増分の結果

将来予測ケース	最大沈下増分(cm)	最大年間沈下(cm/year)	沈下5cm以上(Km2)	沈下10cm以上(Km2)	沈下15cm以上(Km2)	沈下20cm以上(Km2)
CASE-1（揚水現状維持）	28.8	1.9	98.5	42.5	22.7	12.4
CASE-2（白石揚水30%削減）	22.1	1.5	69.3	25.3	10.3	0.7
CASE-3（白石揚水50%削減）	15.5	1	40.1	11.6	0.21	0

成果

(1) GISの空間情報の管理･解析機能を活用した地下水揚水時空分布解析，地下水涵養時空分布解析，地下水流動解析の3つのモデルからなる**広域水循環時空解析システム**の構築を行った．

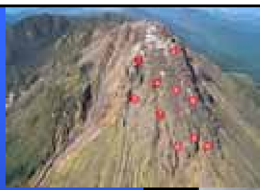
(2) 筑後佐賀平野の**地下水揚水量の時空分布**を初めて算出した．

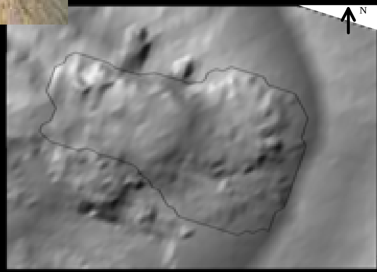
(3) 平野全体での涵養は粘土層が存在する平野部ではほとんどなく，**山地部からが主**であることが時空的に示された．

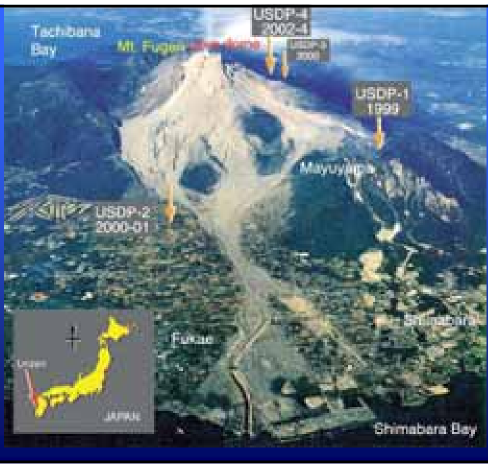
(4) 地下水の**季節的な変動**を広域的に再現できた．

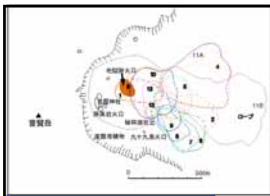
(5) 構築したモデルは**渇水時の対策･長期的水利活用･地盤沈下対策の意思決定支援**に有効である．

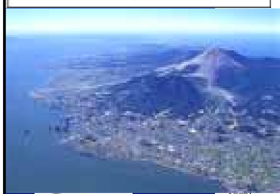
雲仙普賢岳 第11ローブの安定性の検討

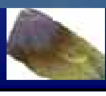


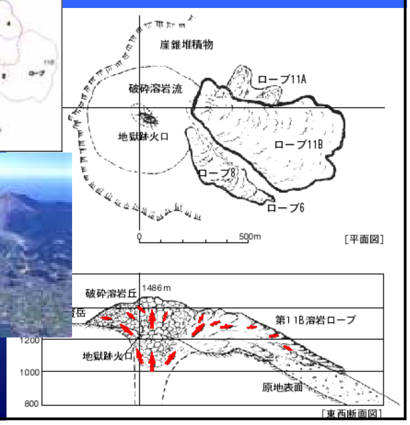




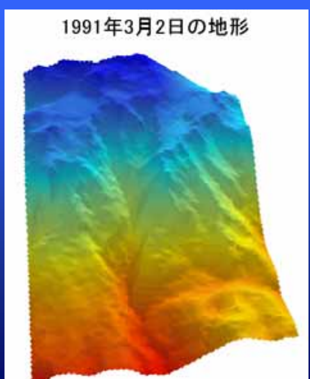


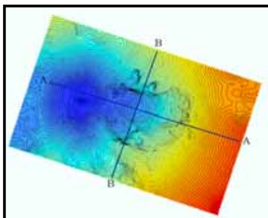






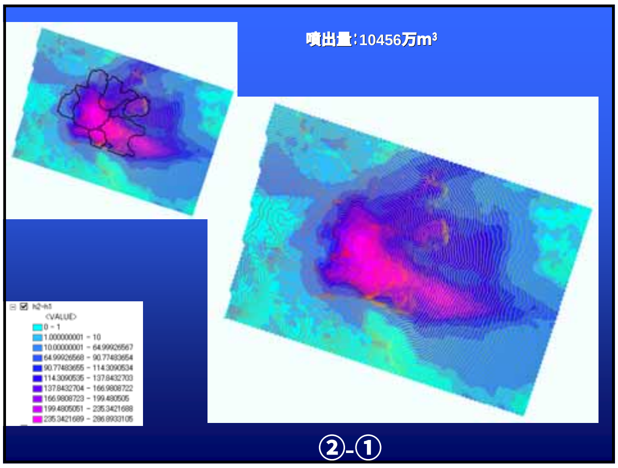
地形の動態変化

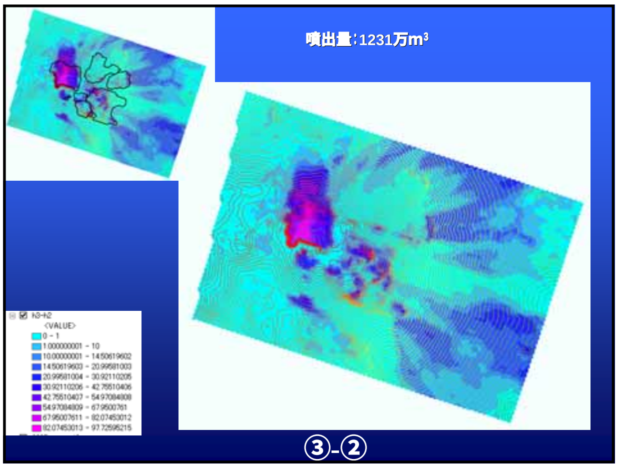


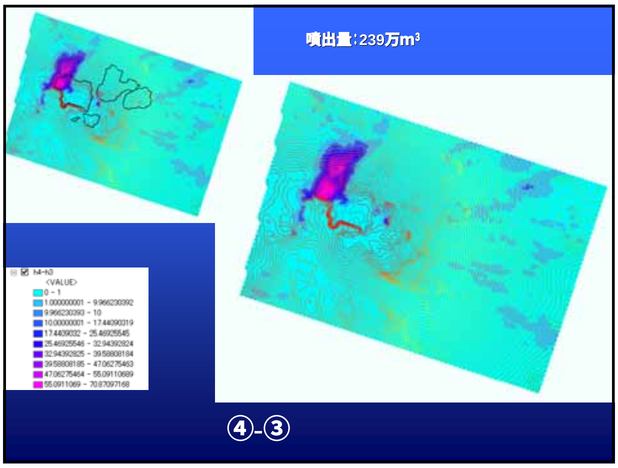


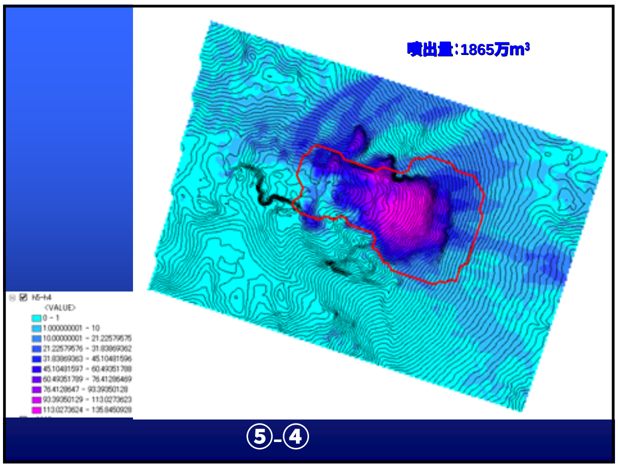
断面図作成側線位置

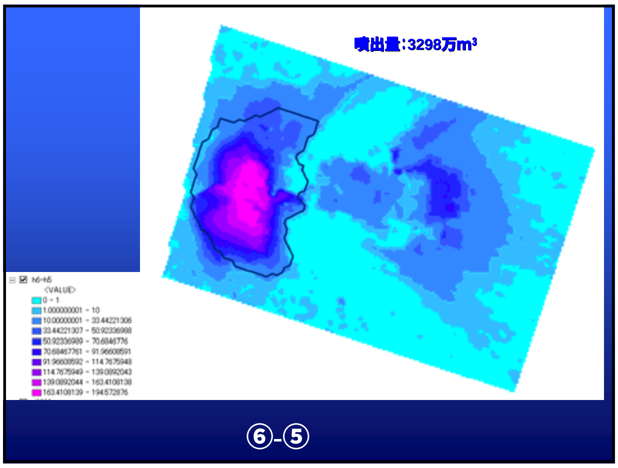
断面図A-A

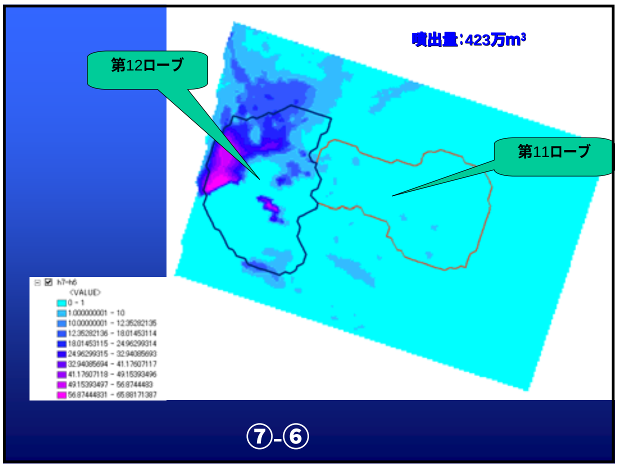

噴出量:10456万m³
②-①


噴出量:1231万m³
③-②


噴出量:239万m³
④-③

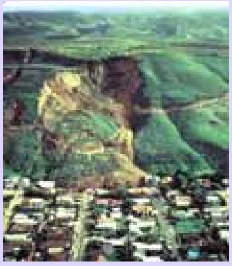

噴出量:1865万m³
⑤-④


噴出量:3298万m³
⑥-⑤


噴出量:423万m³
第12ローブ
第11ローブ
⑦-⑥

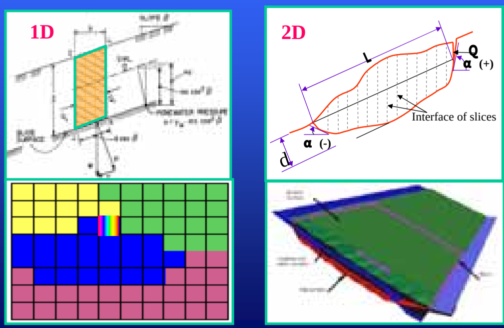
現状の問題点：

- 二次元斜面安定解析技術は成熟，しかし三次元問題である．
- 自然斜面のどこが？，どの規模で崩壊するか？
  そして，いつ発生するか？
- データは整備されてきたが，活用しているか？



目的：GISの高度利用によって，広域にわたる自然斜面を対象とする三次元斜面崩壊予測システムを開発する

1D or 2D Slope Stability



斜面崩壊予測のためのGIS三次元解析システムの開発

ー3D SSAS(3D Slope Stability Analysis System)ー

九州大学大学院　工学研究院
環境システム科学研究センター
江崎哲郎，三谷泰浩，邱騁，謝謨文

解析理論の開発

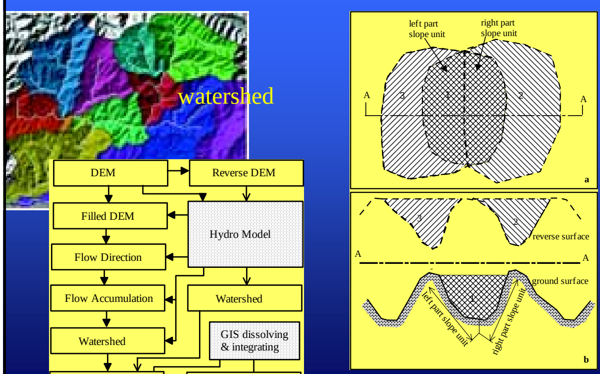
①Slope Unitの区分～広域の複雑な地形の中から，同じ傾斜方向を持つ領域を区分

②　三次元解析用の地形，地質区分，地下水位，不連続面などのベクトル，ラスターデータの準備

③すべり体を楕円球体と仮定し，斜面の傾斜方向に空間姿勢を調整する座標変換

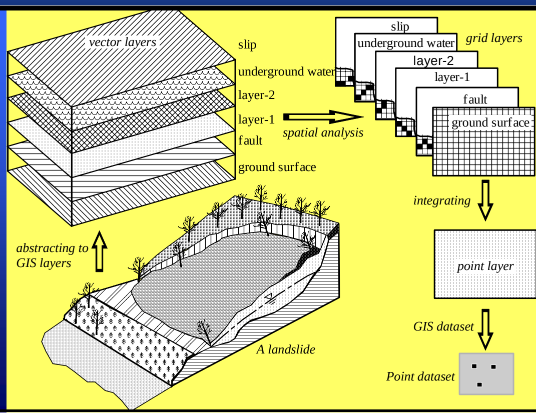
④モンテカルロ法により，すべり体の中心位置，長さ，幅，深さについて一様乱数を発生させて，繰り返し三次元安定計算を行ない最小安全率すべり体を抽出

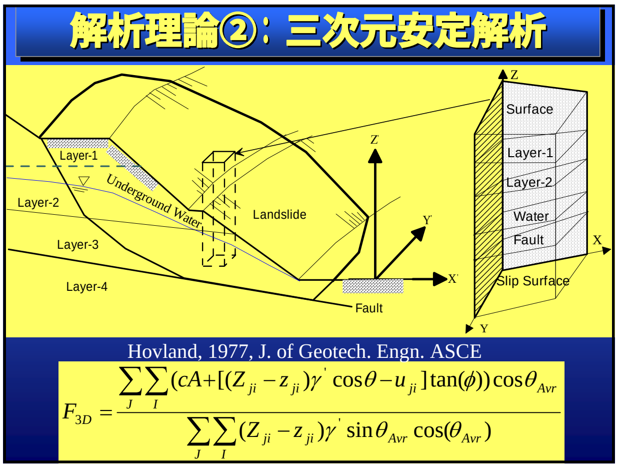
解析理論①：SlopeUnitの区分

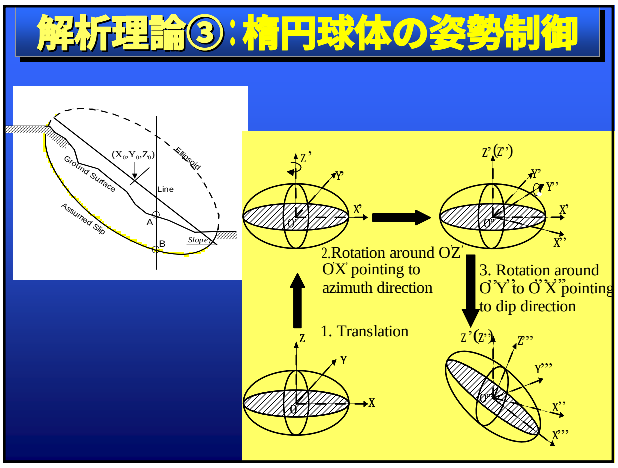


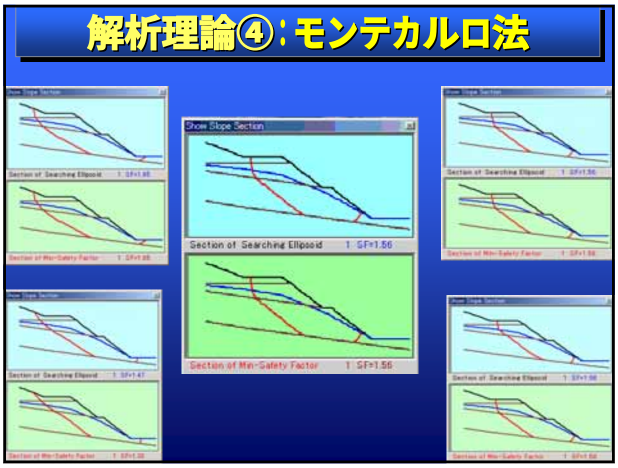
GIS Hydro-model based method

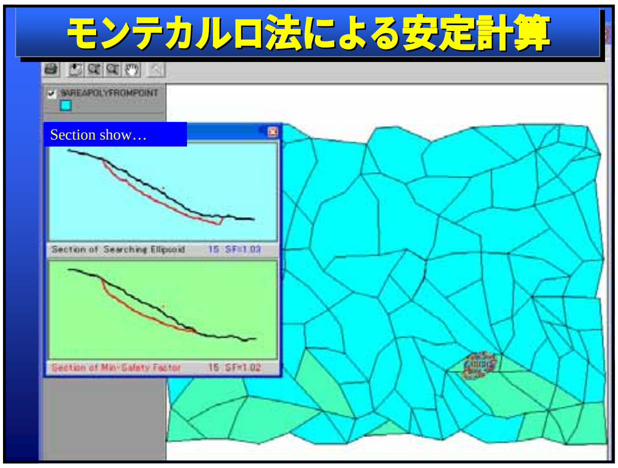
解析理論②：ベクトル・ラスターデータ

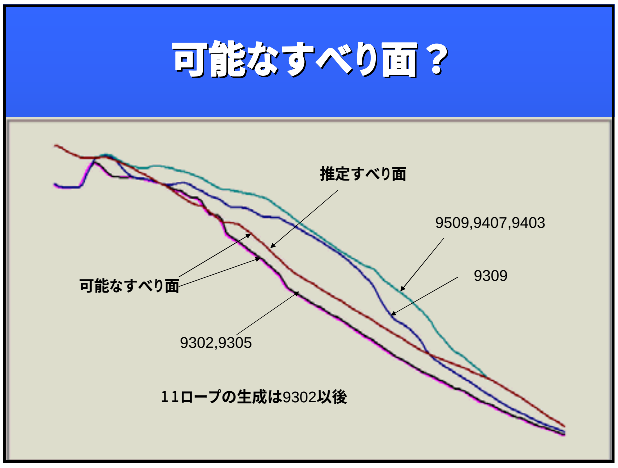


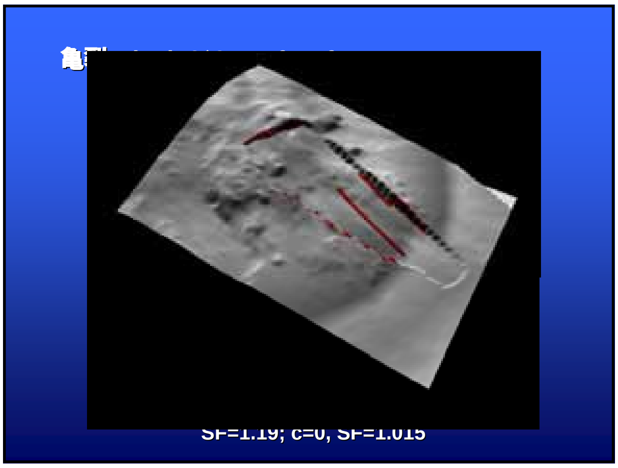

解析理論②：三次元安定解析
Layer-1
Layer-2
Layer-3
Layer-4
Underground Water
Landslide
Fault
Surface
Layer-1
Layer-2
Water
Fault
Slip Surface
Z
X
Y
Hovland, 1977, J. of Geotech. Engn. ASCE
$F_{3D} = \frac{\sum_J \sum_I (cA + [(Z_{ji} - z_{ji})\gamma' \cos\theta - u_{ji}] \tan(\phi)) \cos\theta_{Avr}}{\sum_J \sum_I (Z_{ji} - z_{ji})\gamma' \sin\theta_{Avr} \cos(\theta_{Avr})}$


解析理論③：楕円球体の姿勢制御
Ground Surface
Assumed Slip
Ellipsoid
Line
Slope
1. Translation
2.Rotation around O'Z' O'X' pointing to azimuth direction
3. Rotation around O'Y' to O'X'' pointing to dip direction

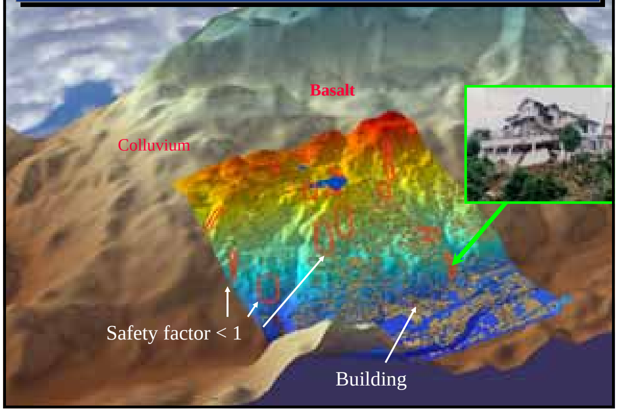

解析理論④：モンテカルロ法
Show Slope Section
Section of Searching Ellipsoid 1 SF=1.56
Section of Min-Safety Factor 1 SF=1.56


モンテカルロ法による安定計算
SAREAPOLYFROMPOINT
Section show…
Section of Searching Ellipsoid 15 SF=1.03
Section of Min-Safety Factor 15 SF=1.02


可能なすべり面？
推定すべり面
9509,9407,9403
9309
可能なすべり面
9302,9305
11ロープの生成は9302以後

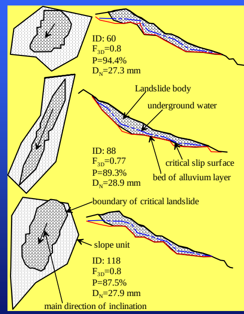

SF=1.19; c=0, SF=1.015

実績例ー1　長崎県地すべり地区

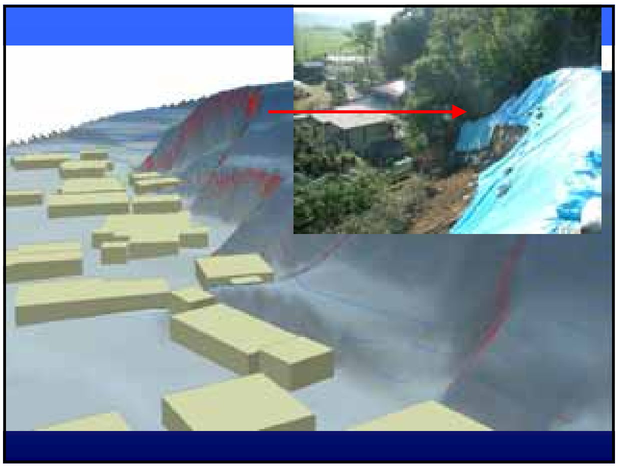


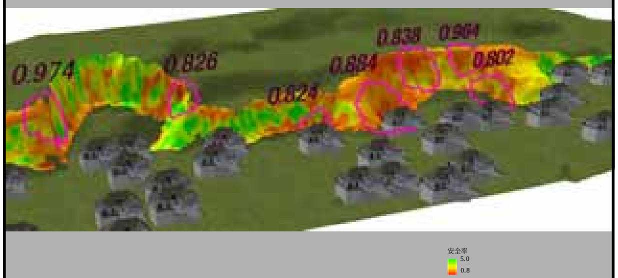
実施例ー1

Plane distribution



Some sections





まとめ

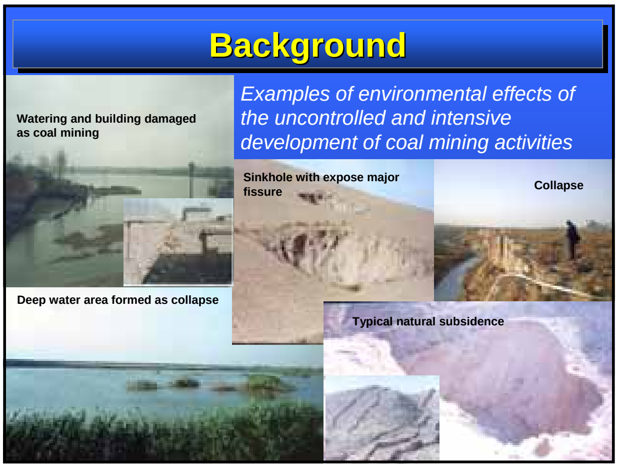
- 三次元斜面安定解析法とGIS技術を結合することによって、従来不可能であった広域自然斜面の三次元斜面安定評価を実現した。
- GIS技術の高度利用によって、データの読込、処理、解析、および計算結果の表示がすべてGIS内部で行われる。
- 安全率の評価だけではなく、危険箇所の位置の抽出、すべり体の空間形状、崩壊規模なども特定できる。

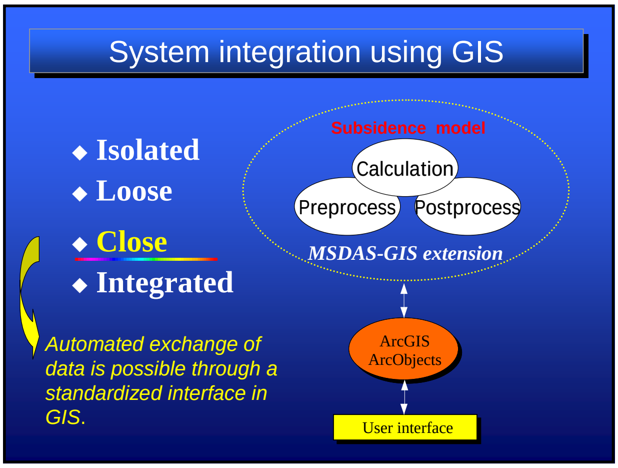
Development of GIS-based Spatial and Dynamic Subsidence Prediction System Above Complex Underground Mining

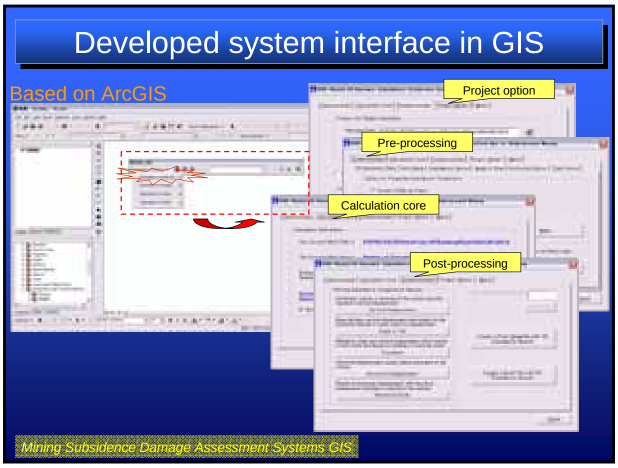
31st International Conference of Safety In Mines Research Institutes
October 2-5, 2005

• Tetsuro ESAKI
Ibrahim DJAMALUDDIN
Yasuhiro MITANI

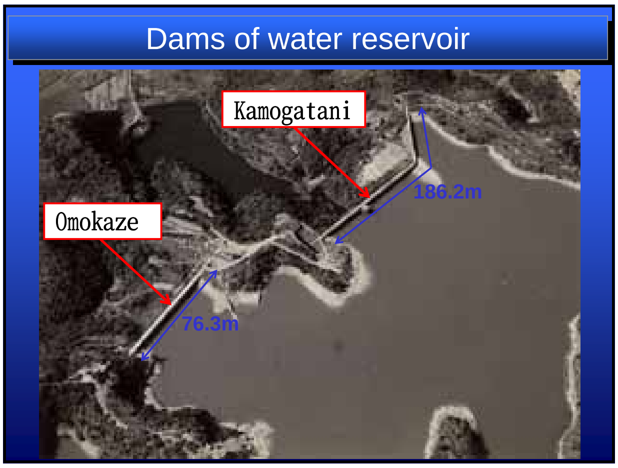
Kyushu University, JAPAN

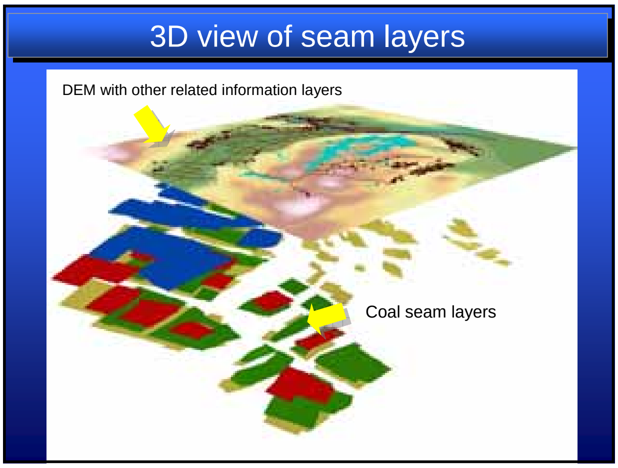


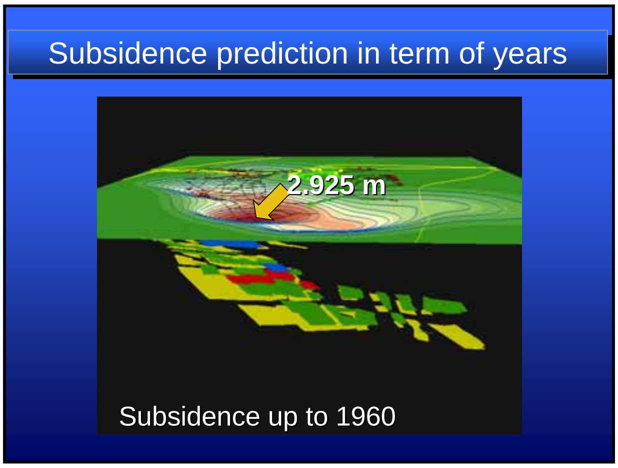


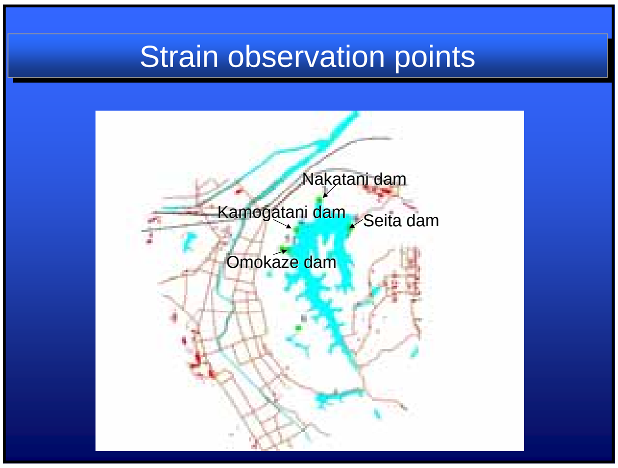


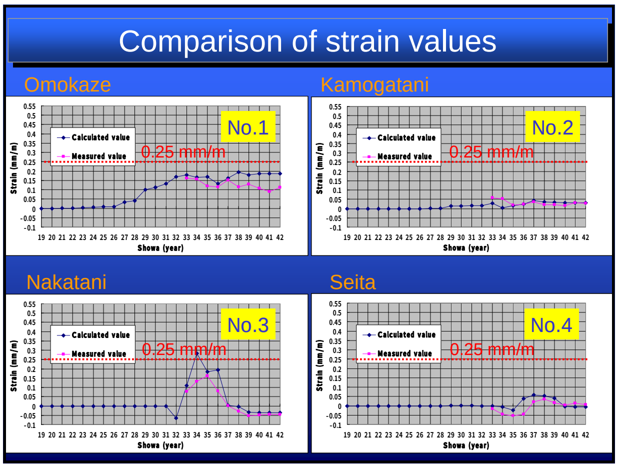
3. A case study: subsidence prediction and protection of water reservoir against subsidence damage in Japanese coal mining

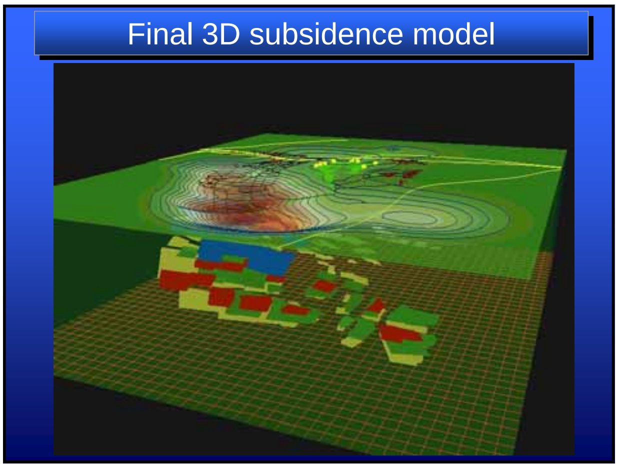




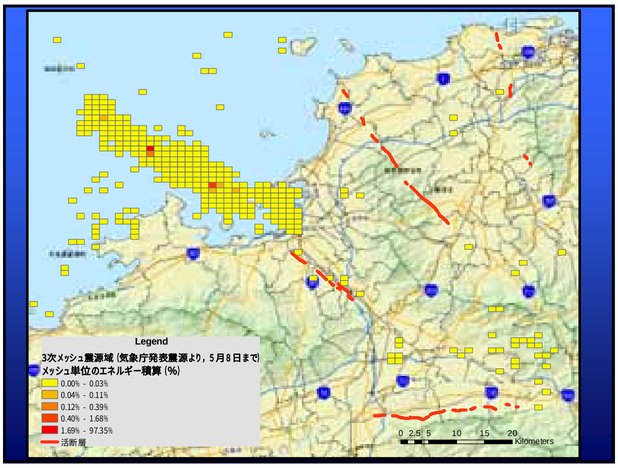

Subsidence prediction in term of years
2.925 m
Subsidence up to 1960

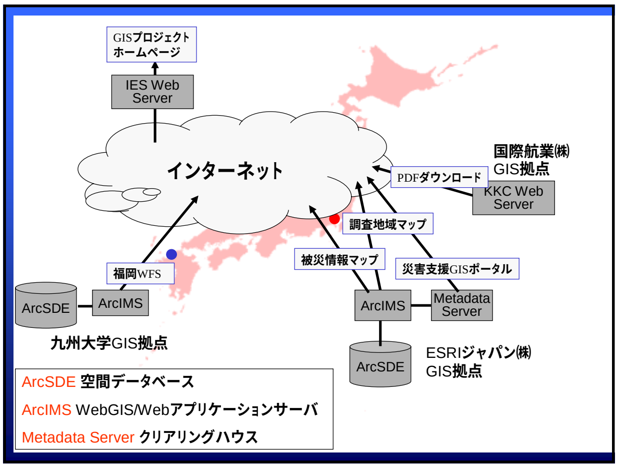

Strain observation points
Nakatani dam
Kamogatani dam
Seita dam
Omokaze dam

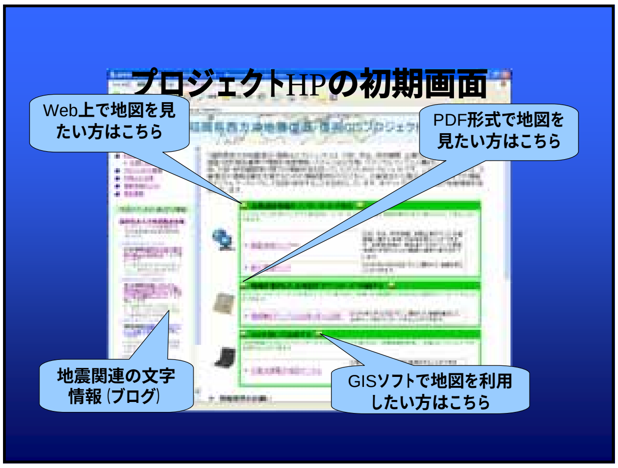

Comparison of strain values
Omokaze
No.1
Kamogatani
No.2
Nakatani
No.3
Seita
No.4
0.25 mm/m
Calculated value
Measured value
Strain (mm/m)
Showa (year)


Final 3D subsidence model


福岡県西方沖地震
復興・復旧GISプロジェクト


Legend
3次メッシュ震源域 (気象庁発表震源より，5月8日まで)
メッシュ単位のエネルギー積算 (%)
0.00% - 0.03%
0.04% - 0.11%
0.12% - 0.39%
0.40% - 1.68%
1.69% - 97.35%
活断層
0 2.5 5 10 15 20
Kilometers





GISが普及するための条件

①データの整備・維持管理

②ハード（インターネットGIS、高速通信網）

③ソフト（優れたソフト、共通規格）

④人材育成（企画能力、ソフトを使う訓練）

⑤ TIPS & TRICK

（技術相談、教えあう環境）

これからのGIS情報システムに要求される条件

- 業務の効率化，費用削減
- 従来の業務に置き換わる，常時使用する
- 情報公開、透明性，セキュリティ対応
- インターネット接続、国際レベルでの互換性
- 将来起きるであろう新規の様々な要求に対して，柔軟に、迅速に、経済的に対応できる
- 初期費用，維持費用が安価である
- 維持管理，変更が容易，陳腐化しない

GIS基礎技術研究会

・平成9年発足　今年10年目．代表者：江崎哲郎

・これまでに93回の講演会・実習を行った．（GIS学会共催など）

実習の受講者（技術者，教員,大学院生）は陳べ400名

・毎月第三土曜日，九大工学部，午前講演，午後実習

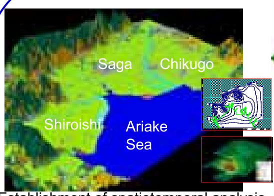

http://www.ies.kyushu-u.ac.jp/~geo/

GIS APPLICATIONS IN ROCK ENGINEERING

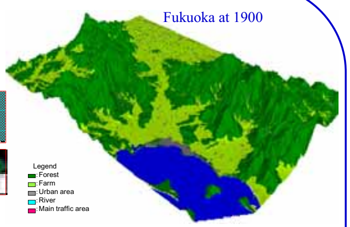
Introduction

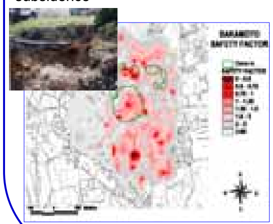
GIS (Geographic Information System) is the system to capture, store, integrate, and analyze data, which are spatially referenced to the Earth. The GIS is recognized as an important tool for the advanced information society of the 21st century. In order to harmonize developments with environments, our laboratory actively studies to predict, monitor, assess, and reduce the impact of developments on natural and social environments using the GIS technology. We also evolve the research with emphasis on the collaboration between industry, government, and academe.

GEO-ENVIRONMENT

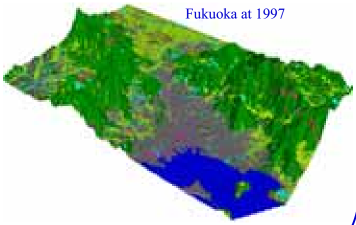


Establishment of spatiotemporal analysis system for water circulation and land subsidence



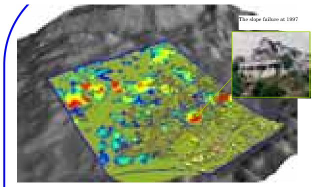


A hazard map of shallow subsidence



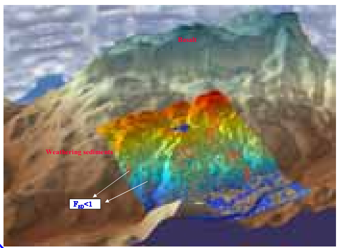
GIS analysis for the history of land use for 100 years

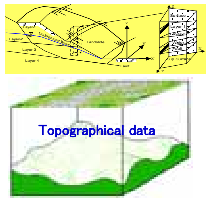
DISERSTERS PREVENTION / PREDICTION



A precision landslide hazard map in Sasebo, Nagasaki

Simulation of landslide due to the torrential rain in Minamata, Kumamoto

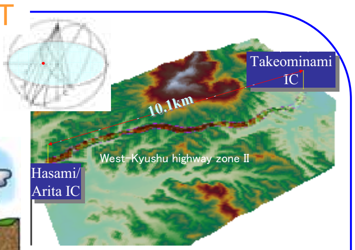




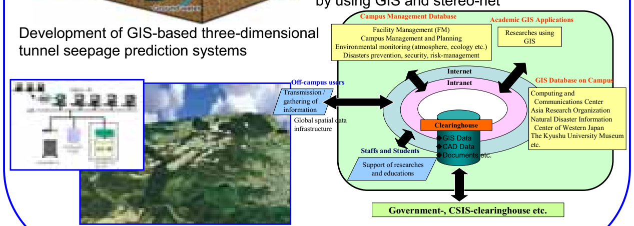
3D landslide hazard mapping

MANAGEMENT

Development of GIS-based three-dimensional tunnel seepage prediction systems

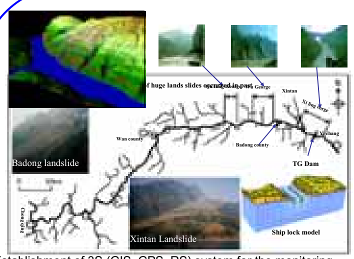


Stability assessment of Tertiary stratified slope by using GIS and stereo-net

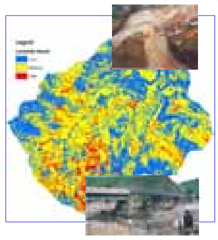


Establishment of Self-Regulated and Distributed Spatial Information System

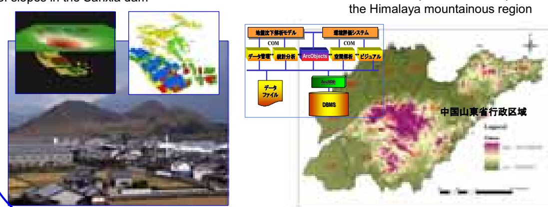
INTERNATIONAL PROJECTS



Establishment of 3S (GIS, GPS, RS) system for the monitoring of slopes in the Sanxia dam



A hazard map of the rock slope disaster in the Himalaya mountainous region



Subsidence due to the underground mining in northern China, and its environmental prediction and conservation measures

Technologies

・Geo-environment
・GIS applications
・Analysis of Spatiotemporal data

Needs

・Environments, disasters prevention
・Infrastructure and management for safety and reliable society
・Risk-management, decision-making systems

Institute of Environmental Systems, Faculty of Engineering, Kyushu University, Fukuoka, Japan
Tetsuro ESAKI, Yasuhiro MITANI, Hiro IKEMI E-mail esaki@, mitani@, ikemi@ies.kyushu-u.ac.jp

DEVELOPMENT OF TUNNEL SEEPAGE AND SHORTAGE OF GROUNDWATER PREDICTION SYSTEM

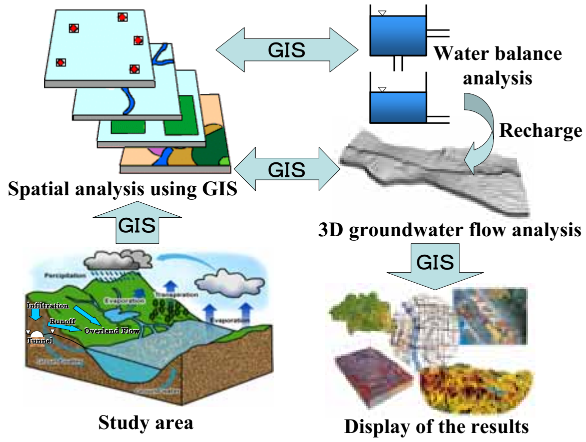
Introductions

Seepage due to tunnel excavation affects construction schedules, costs and safety. It is important to predict quantitatively the seepage. Environmental assessment such as the shortage of groundwater in surrounding area has been also required.

Previously, a number of the tunnel seepage prediction methods were proposed. In this research, to understand the tunnel seepage and the shortage of groundwater temporally and spatially, GIS (geographic information system) and a numerical method are used to develop the tunnel seepage predication system.

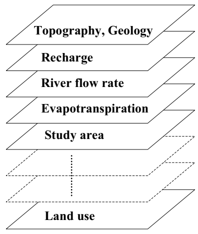
Contents

Summary of the System

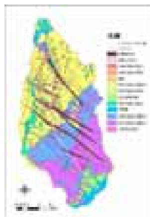


Data management

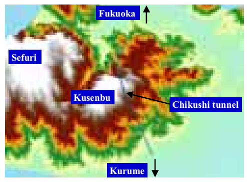
Study area



Data management using GIS

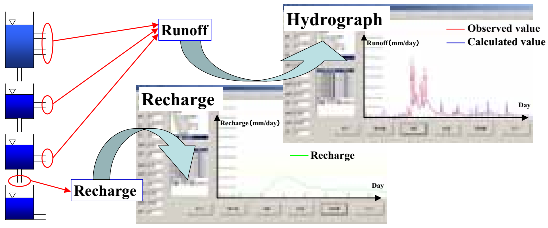


Geological Map

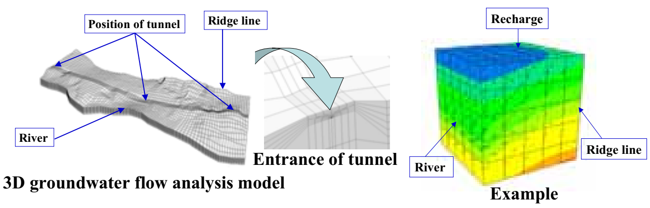


Topography

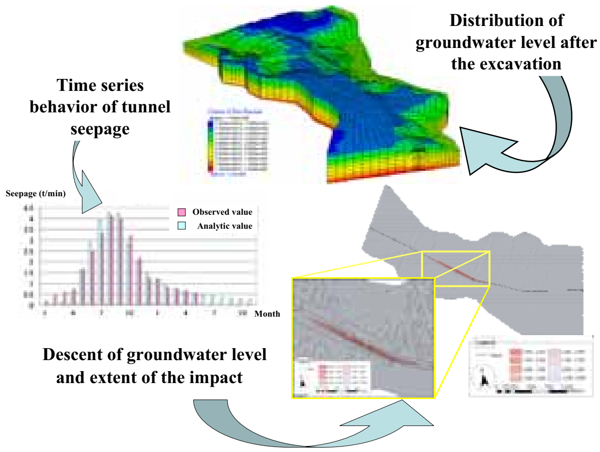
Water balance analysis using TankModel



3D groundwater flow analysis



Display of the results



Conclusions

The tunnel seepage predication system, which considers hydrological cycle, topography, and geology, has been developed, and applied to the case study in order to examine the validity of this system. The GIS can efficiently divide drainage area, classify the land use, create the 3D mesh data, and set initial groundwater level. Additionally, this system makes it possible to examine descent of groundwater level and extent of impacts.

Institute of Environmental Systems, Faculty of Engineering, Kyushu University, Fukuoka, Japan

Tetsuro ESAKI, Yasuhiro MITANI, Hiro IKEMI E-mail esaki@, mitani@, ikemi@ies.kyushu-u.ac.jp

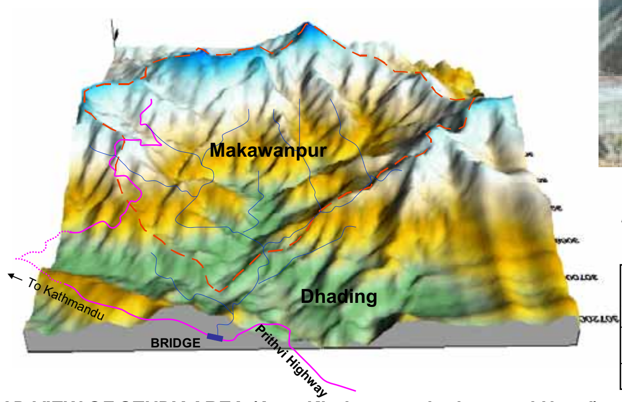
GIS BASED PREDICTION MODELLING OF LANDSLIDES AND DEBRISFLOWS HAZARD IN MOUNTAINOUS TERRAIN, CENTRAL NEPAL

Introduction

Extreme weather event of 19 - 21 July 1993 triggered off a large number of landslides and debrisflows in the Agra Khola watershed of central Nepal. A prediction model is performed to assess landslides and debrisflows hazard in mountainous terrain by using Geographic Information System (GIS). The model is based on spatial integration of multivariate data.

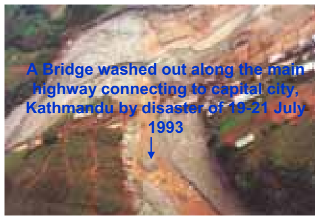
Objectives of the research are: (1) to characterize landslides and debrisflows in mountainous terrain (2) to define spatial correlation of landslides and debrisflows, and causative factors, and (3) to improve the hazard modelling techniques in mountainous terrains and its application.

Contents

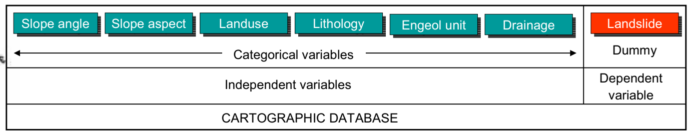


3D VIEW OF STUDY AREA (Agra Khola watershed, central Nepal)
(latitudes 27°45'-27°36' N and longitudes 84°58'-85°7' E)

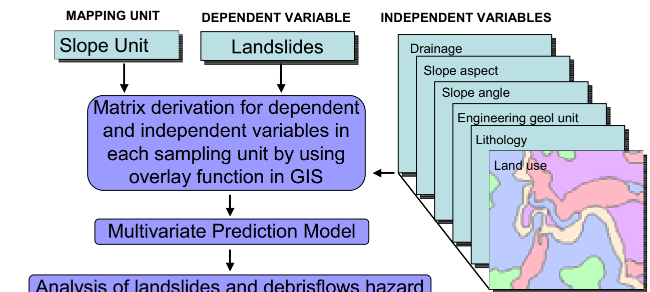
LANDSLIDES AND DEBRISFLOWS

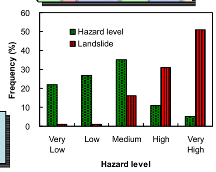


DAMAGE BY JULY 1993 DISASTER



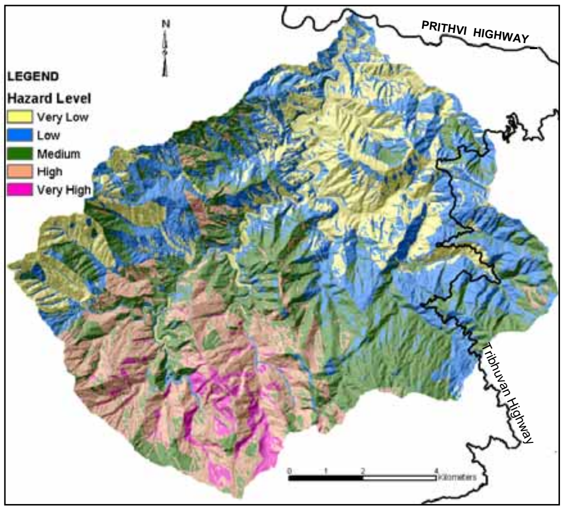
SPATIAL DATABASE DESIGN IN GIS





Validation of prediction model

FLOW CHART FOR PREDICTION MODEL IN GIS



LANDSLIDES AND DEBRISFLOWS HAZARD MAP OF AGRA KHOLA WATERSHED, CENTRAL NEPAL BY SPATIAL INTEGRATION MULTIVARIATE DATA

Conclusions

GIS Based Prediction Model illustrates spatial integration of multivariate data to quantify landslides and debrisflows hazard in mountainous terrain. The model also demonstrates effective use of GIS functions to define hazard for data rarity and complexity of mountain terrains.

Institute of Environmental Systems, Faculty of Engineering, Kyushu University, Fukuoka, Japan

Tetsuro ESAKI, Yasuhiro MITANI, Hiro IKEMI E-mail esaki@, mitani@, ikemi@ies.kyushu-u.ac.jp

SHEAR – FLOW COUPLING PROPERTIES OF ROCK JOINT

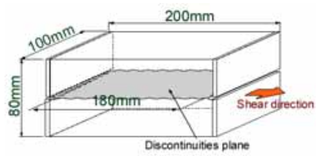
Introduction

Deep underground structures utilize rock characteristics such as stiffness, sealing, durability and isolation. It is important to obtain the permeability of the rock mass, in which underground structures are to be constructed in order to confirm its capacity to isolate. Permeability in rock masses containing multiple joint sets is principally governed by those joints. The permeability of a rock joint fundamentally depends on its behavior in opening and closing, it is necessary to understand the coupling between the hydraulic and mechanical mechanisms.

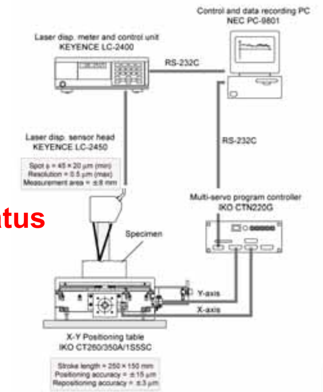
Contents

The shear-flow coupling properties of a rock joint are clarified from laboratory tests. Aperture distribution is determined using joint surface data and a shear-flow coupling model is developed. The shear-flow coupling tests are simulated in order to clarify the mechanisms of shear-flow coupling properties and compared with experimental results.

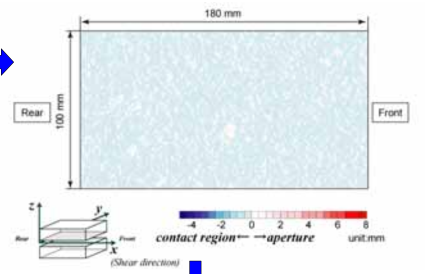
Specimen



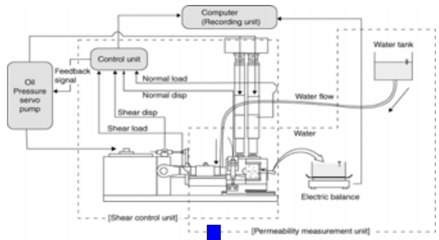
Joint surface measurement



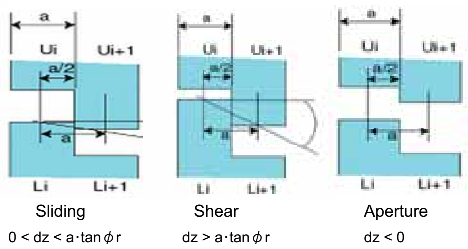
Setting initial aperture



Shear – flow coupling test apparatus



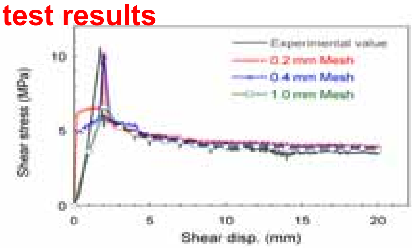
Shear model

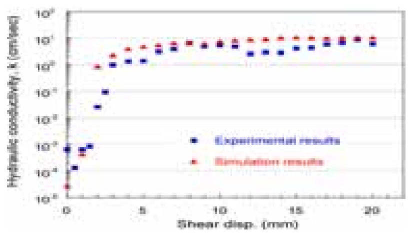


Aperture distribution during Shear displacements

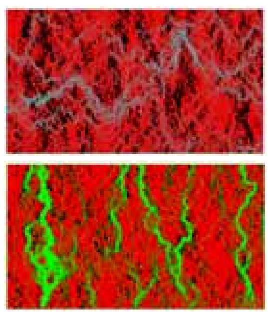
Comparison of simulation with test results

Shear stress versus Sear displacement

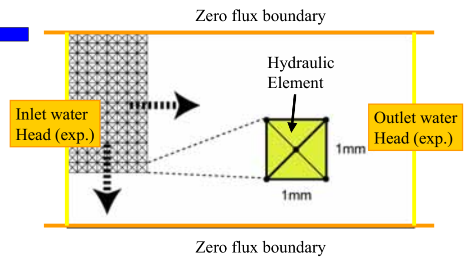




Flow simulation



Flow model



Conclusions

The proposed shear – flow model simulates the variation of shear stress and hydraulic conductivity during shear relatively in good agreement with experimental test results, according to the aperture and contact distribution. Further research for measurement and characterization of joint geometry to accurate simulation of coupling processes is ongoing.

Institute of Environmental Systems, Faculty of Engineering, Kyushu University, Fukuoka, Japan

Tetsuro ESAKI, Yasuhiro MITANI, Hiro IKEMI E-mail esaki@, mitani@, ikemi@ies.kyushu-u.ac.jp

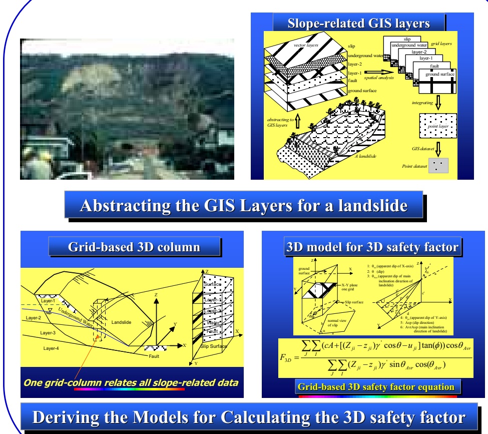
DEVELOPMENT OF GIS-BASED SPATIAL THREE-DIMENSIONAL SLOPE SPATIAL STABILITY ANALYSIS SYSTEM: 3DSlopeGIS SYSTEM

Abstract

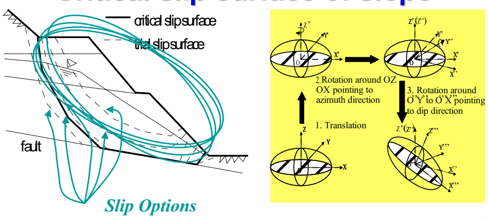
Based on a new IT technology-Geographic Information System (GIS), this study presents a new slope analysis approach which can be used to identify the possible slope failure bodies from complicated topography. In a system, all slope-related spatial information (vector or raster dataset) are integrated; the study area is divided into Slope Unit which possesses approximate inclination; assuming the initial slip to be the lower part of an ellipsoid, the 3-D critical slip surface in the 3-D slope stability analysis is located by minimizing the 3-D safety factor using the Monte Carlo random simulation.

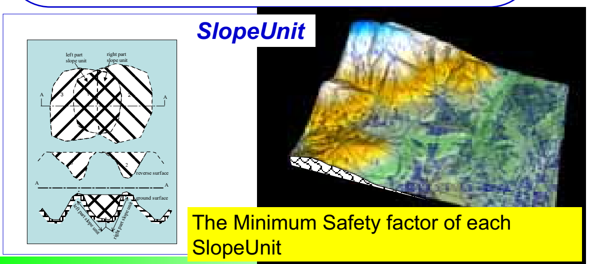
Contents

GIS-grid based 3D models

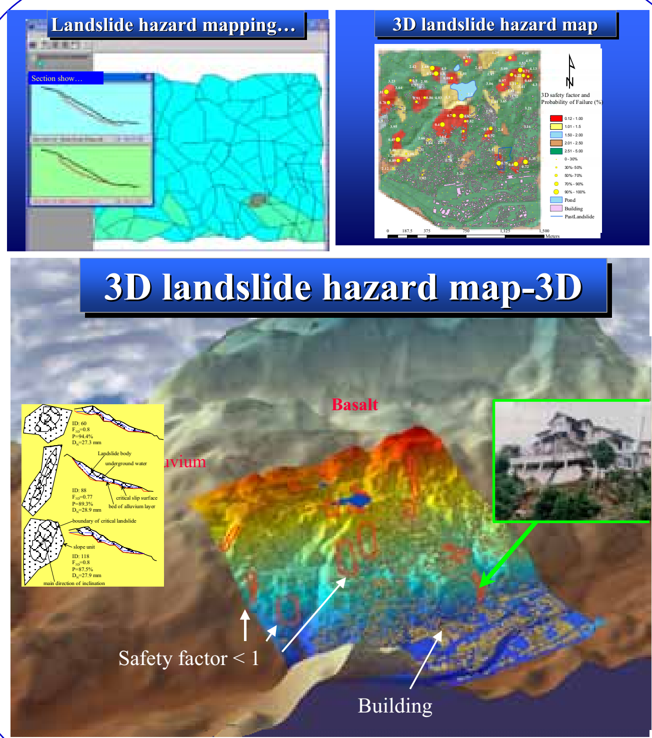


Monte Carlo Simulation for Critical slip surface of slope

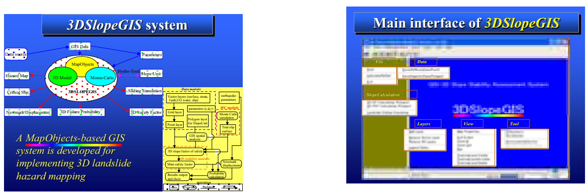




3D Landslide hazard mapping



A GIS-based system-3DSlopeGIS



Conclusions

A GIS-based system of 3DSlopeGIS has been developed for evaluate the possible slope failure of a hilly area. A new Geographic Information Systems (GIS) grid-based 3-D deterministic model has been used to zone possible slope failure using the index of the 3-D safety factor of slope.

Institute of Environmental Systems, Faculty of Engineering, Kyushu University, Fukuoka, Japan

Tetsuro ESAKI, Yasuhiro MITANI, Hiro IKEMI E-mail esaki@, mitani@, ikemi@ies.kyushu-u.ac.jp