



2022 한국수자원학회 학술발표대회

QGIS-GRM 모델 개발 및 적용사례

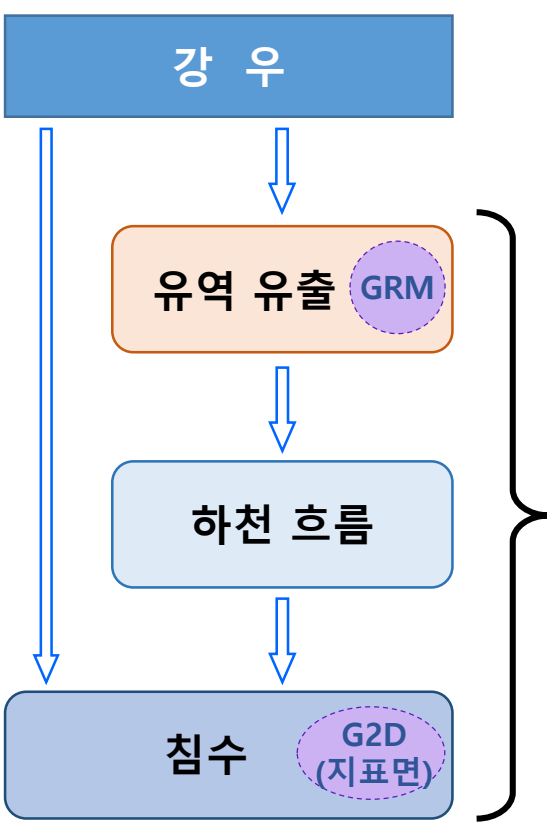
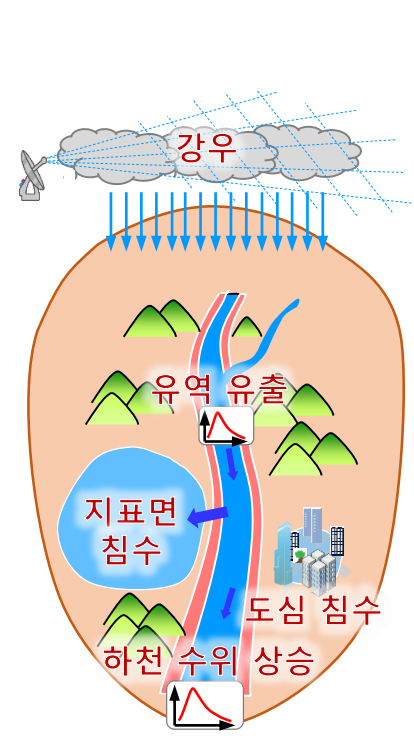
환경부 R&D : 골든타임 확보를 위한 유역 시공간 상세 홍수예보기술개발(4세부 : 행정구역 홍수정보 생산 기술 개발)

DATE_ 2022. 05. 19.

발 표 자_ 최윤석, 김경탁, 최천규
소 속_ 한국건설기술연구원



1. 개요 - 일반적인 홍수해석 모델의 범위

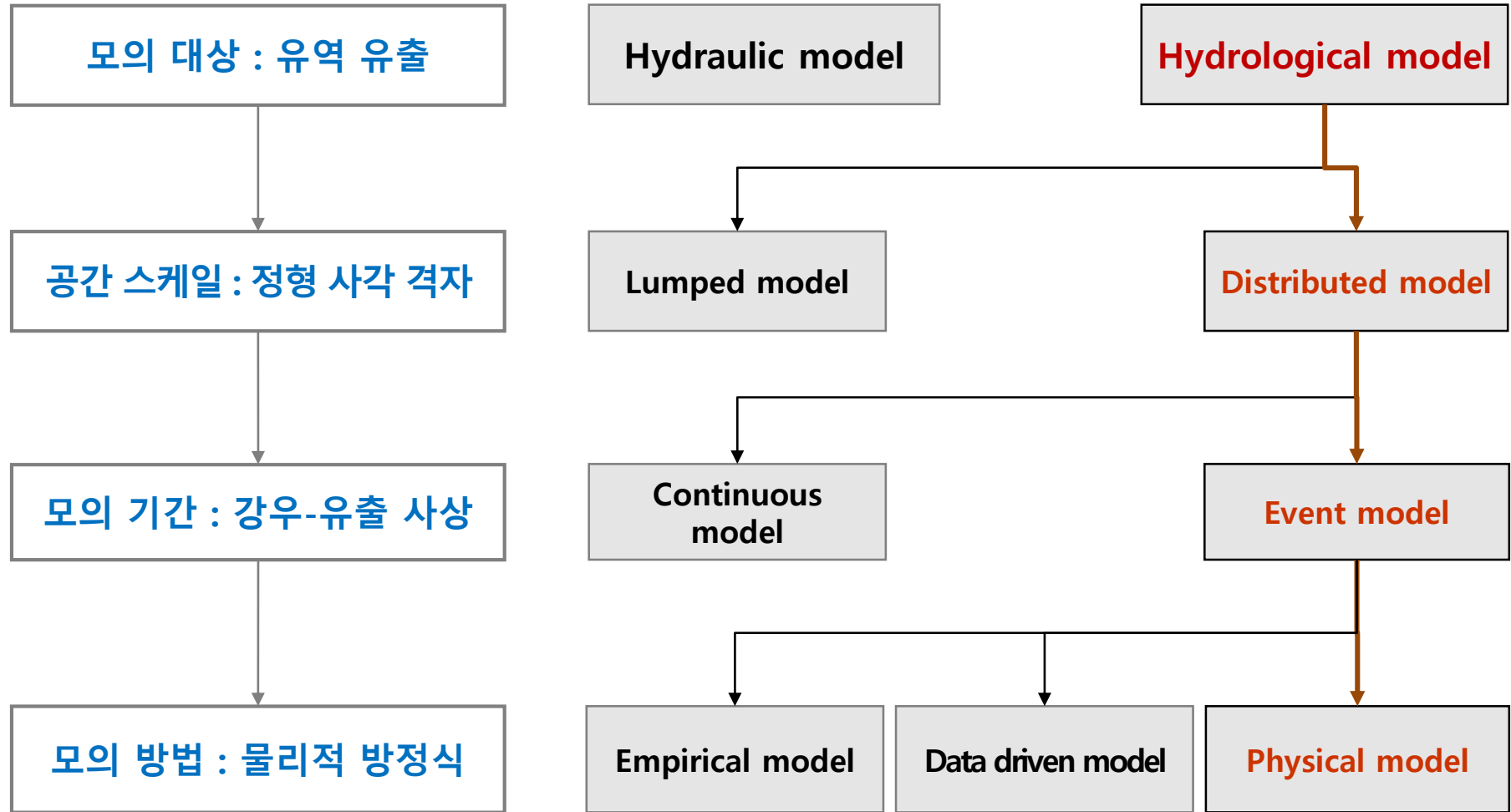


홍수해석
모델
범위

- 모의대상
 - 강우의 토양 침투, 증발산, 융설
 - 지표면 흐름, 지표하 흐름, 하천 흐름 (유량, 수심, 유속 등)
- 계산방법
 - 물리적, 경험적, 통계적 방정식 적용
 - 1차원, 2차원 해석
 - 모델링 S/W 개발 및 활용
- 활용분야
 - 홍수예보
 - 홍수 후 상황, 수문학적 거동 분석
 - 홍수대비·대응 계획 수립



1. 개요 – GRM 모델의 개략적 분류



2. GRM 모델

- 모의 대상
 - 유역 유출 해석 모델(유역에서 하천으로 유입되는 유량 계산)
 - 침투, 침누, 지표하 유출, 기저유출, 지표면 흐름, 하천 흐름, 저수지

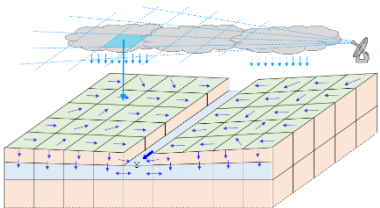
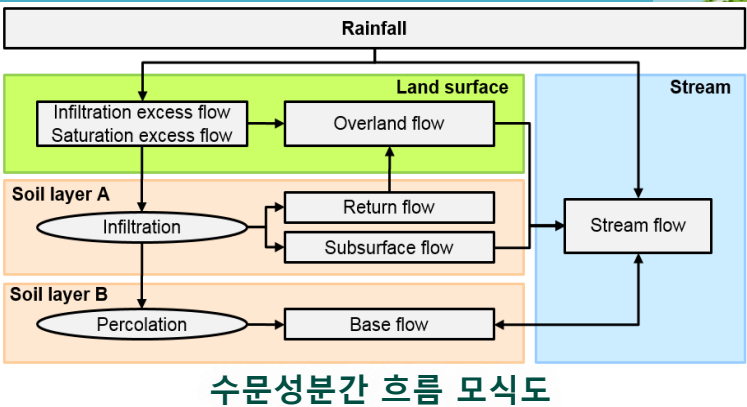
- 계산 방법
 - 주요 방정식 : Kinematic wave eq., Green-Ampt eq.
 - 격자 기반의 분포형 모형(→ 고해상도 홍수모의)
 - 1차원 흐름 해석
 - CPU 기반 병렬계산

- 주요 history
 - 2008 : 최초 버전 릴리즈 (HyGIS-GRM)
 - 2014 : Free S/W로 전환
 - 2017 : GitHub 오픈소스로 전환 (<https://github.com/floodmodel/GRM>)

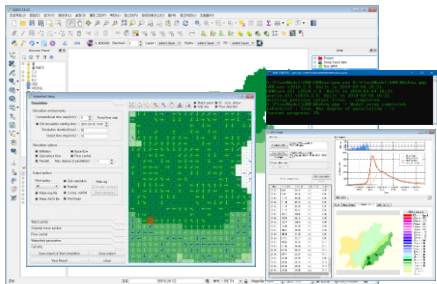
WMO 홍수모의 분야 대표 모형 중 하나로 채택

<https://www.floodmanagementinfo/e2e-ews-ff-community-of-practice-area/resources/inventory/>

- '17 ~ 현재 : 국가홍수예보시스템 구축 연구사업 진행 중
(골든타임 확보를 위한 유역 시공간 상세 홍수예보기술개발)



격자 단위 흐름 모식도



모델링 S/W(QGIS-GRM)

A screenshot of the WMO inventory website. It shows a table of models and platforms available for flood forecasting. The table has columns for 'Type', 'Short name', 'Long name', and 'Link'. The 'GRM' model is highlighted in the table.

Type	Short name	Long name	Link
Hydrologic	HEC-HMS	Hydrologic Modeling System	Click here to go to the model page
Reservoir	HEC-RAS	Hydrologic Engineering Center Reservoir System Simulation	Click here to go to the model page
Hydrodynamic	HEC-RAS 2D	Hydrologic Engineering Center's (CEM) HEC-RAS River Analysis System (HEC-RAS)	Click here to go to the model page
Platforms	GRM	Grid-based rainfall-runoff model	Click here to go to the model page
Hydrologic	GRM	Grid-based rainfall-runoff model	Click here to go to the model page

A screenshot of the GRM model page on the WMO inventory website. It provides detailed information about the GRM model, including its purpose, background, and how to use it. The page is titled 'GRM' and includes a 'Download Area' section.

WMO inventory

2. GRM 모델

지배방정식

- Overland flow : $\frac{\partial h}{\partial t} + \frac{\partial q}{\partial x} = r - f + \frac{q_r}{\Delta y}$
- Channel flow : $\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = r \Delta y + q_L + q_{ss} + q_b$
- Manning's eq. $u = \frac{R^{2/3} S_0^{1/2}}{n}$

- Infiltration $F(t) = Kt + \Delta\theta\psi \ln(1 + \frac{F(t)}{\Delta\theta\psi}) \quad f(t) = K(\frac{\psi\Delta\theta}{F(t)} + 1)$

- Subsurface flow : $q_{ss} = KD_s \sin(S_a)$

- Percolation : $p = K_{Bv} \times \Delta t$

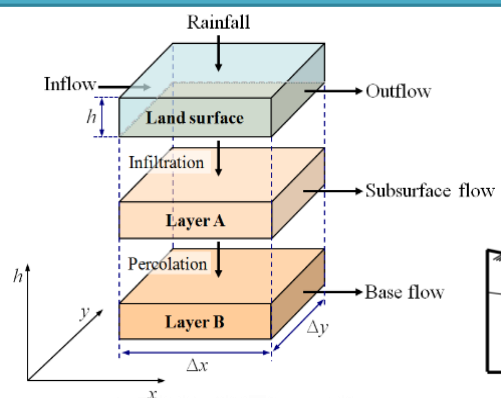
Lateral flow in soil layer B

$$q_{Bh} = K_{Bh} D_B \frac{dz_B}{dx} = K_{Bh} D_B \sin(S_a)$$

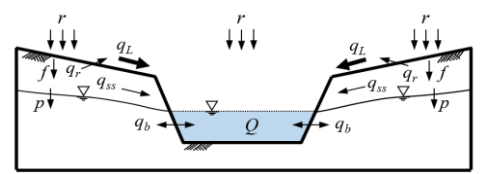
Baseflow

$$q_b = K_{Bh} \frac{h_B - h_{ch}}{h_{ch}} b \quad (\text{for } h_B > h_{ch})$$
$$q_b = K_{Bh} (h_B - h_{ch}) \quad (\text{for } h_B < h_{ch})$$

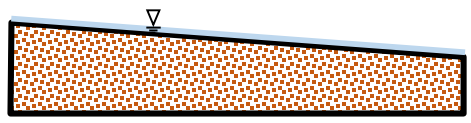
q : 단위 폭당 유량($q=uh$), u : x 방향 유속, r : 강우강도,
 f : 침투율, q_r : 복귀류, A : x 방향에 직각인 흐름 단면적,
 Q : 유량, h : 수심, q_L : 측방유입, q_{ss} : 지표하 유출,
 q_b : 기저유출, t : 시간
 K_{Bv} : B 층에서의 연직 투수계수, p : 침투량
 z_B : B 층의 수위, K_{Bh} : B 층의 횡방향 투수계수,
 D_B : B 층의 수심, q_{Bh} : B 층의 단위폭당 횡방향 유량,
 h_B : 비피압대수층의 수심, h_{ch} : 하도 수심, b : 하폭



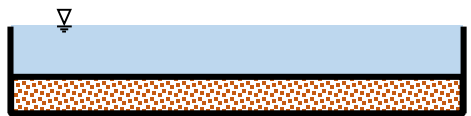
수직층 흐름 모식도



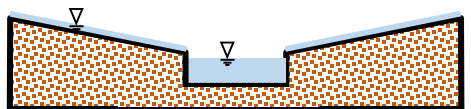
하천 횡단면 흐름 모식도



Overland flow



Channel flow



Channel and overland flows

검사체적 형식



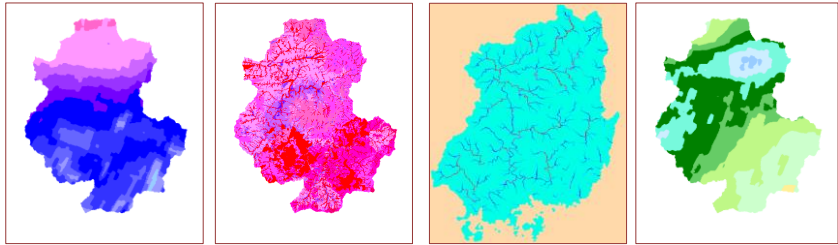
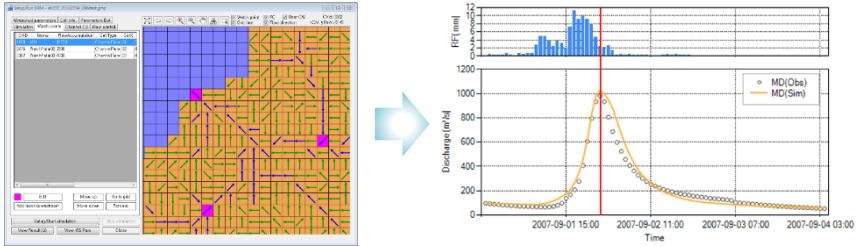
2. GRM 모델

입력자료

Original data	Input data	Format	Required
DEM	Watershed	ASCII raster	O
	Flow direction Flow accumulation	ASCII raster	O
	Slope	ASCII raster	O
	Stream	ASCII raster	Optional (recommended)
Channel width		ASCII raster	Optional
Initial soil saturation ratio		ASCII raster	Optional
Initial stream flow		ASCII raster	Optional
Land cover map	Land cover	ASCII raster	Optional (recommended)
Soil map	Soil texture	ASCII raster	Optional (recommended)
	Soil depth	ASCII raster	Optional (recommended)
Rainfall gauge, radar, satellite	Rainfall(distributed rainfall field or mean areal rainfall)	ASCII raster Text	O
Discharge	Observed discharge	Text	Optional

출력자료

- 모든 Watch point에서의 유량 계산결과, 유역 평균강우량,
- 소요된 계산시간 등
- Flow control 유량 자료
- 저수지 저류량, 유입량
- 대상 watch point에서 출력되는 모든 계산결과
(유량, 기저유량 수심, 토양수분함량, 토양포화도, 격자 강우량,
상류 평균강우량, Flow control 자료, 저류량 등)
- 모의 결과 격자 분포도 ASCII, image raster file



2. GRM 모델



QGIS-GRM plug-in



Watershed setup

Setup Watershed data

Surface topographic layers

Watershed area: GHG_Watershed

Watershed slope: GHG_Slope_ST

Flow direction: GHG_FDir

Flow direction index type

☐ Start from north

☐ Start from northeast

☐ East

☒ Taudem Index

Flow accumulation: GHG_FAc

Channel layer

☒ Stream: GHG_Stream

☐ Channel width: select layer

Initial condition

☐ Ini. soil sat. ratio: select layer

☐ Ini. channel flow: select layer

OK Cancel

Setup rainfall data

Data types

☒ Use ASCII grid files(.asc)[mm]

☐ Use mean areal rainfall text file(.txt,.txt[mm])

Time setup

Rainfall time step[min]: 10

Search rainfall files

C:/GRM/SampleGHG/rainfall

Select folder

Save file name: C:/GRM/SampleGHG/ghg_r_2018

Add selected or all files

OK Cancel

Order	DateTime	Rainfall
1	0	C:/GRM/SampleGHG/rainfall
2	10	C:/GRM/SampleGHG/rainfall
3	20	C:/GRM/SampleGHG/rainfall
4	30	C:/GRM/SampleGHG/rainfall
5	40	C:/GRM/SampleGHG/rainfall
6	50	C:/GRM/SampleGHG/rainfall
7	60	C:/GRM/SampleGHG/rainfall
8	70	C:/GRM/SampleGHG/rainfall
9	80	C:/GRM/SampleGHG/rainfall
10	90	C:/GRM/SampleGHG/rainfall
11	100	C:/GRM/SampleGHG/rainfall
12	110	C:/GRM/SampleGHG/rainfall
13	120	C:/GRM/SampleGHG/rainfall
14	130	C:/GRM/SampleGHG/rainfall
15	140	C:/GRM/SampleGHG/rainfall

Rainfall setup

GRM model project file (.gmp)

```
<?xml version="1.0" standalone="yes"?>
<GRMProject xmlns="http://tempuri.org/GRMProject.xsd">
  <ProjectSettings>
    <ProjectFile>C:/GRM/SampleGHG/GRM500.gmp</ProjectFile>
    <GRMSimulationType>SingleEvent</GRMSimulationType>
    <WatershedFile>C:/GRM/SampleGHG/watershed/GHG_Watershed.asc</WatershedFile>
    <SlopeFile>C:/GRM/SampleGHG/watershed/GHG_Slope_ST.asc</SlopeFile>
    <FlowDirectionFile>C:/GRM/SampleGHG/watershed/GHG_FDir.asc</FlowDirectionFile>
    <FlowAccumFile>C:/GRM/SampleGHG/watershed/GHG_FAc.asc</FlowAccumFile>
    <StreamFile>C:/GRM/SampleGHG/watershed/GHG_Stream.asc</StreamFile>
    <ChannelWidthFile />
    <LandCoverDataType>File</LandCoverDataType>
    <LandCoverFile>C:/GRM/SampleGHG/watershed/GHG_Lc.asc</LandCoverFile>
    <LandCoverVATFile>C:/GRM/SampleGHG/watershed/GHG_Lc_vat</LandCoverVATFile>
    <ConstantRoughnessCoeff />
    <ConstantImperviousRatio />
    <SoilTextureDataType>File</SoilTextureDataType>
    <SoilTextureFile>C:/GRM/SampleGHG/watershed/GHG_SoilTexture.asc</SoilTextureFile>
    <SoilTextureVATFile>C:/GRM/SampleGHG/watershed/GHG_SoilTexture_vat</SoilTextureVATFile>
    <ConstantSoilPorosity />
    <ConstantSoilEffPorosity />
    <ConstantSoilWettingFrontSuctionHead />
  </ProjectSettings>
</GRMProject>
```

Land Cover / Soil

Land cover parameters

☒ Use land cover layer

☐ Use constant value

Land cover: GHG_Lc

VAT file: C:/GRM/SampleGHG/watershed/GHG_Lc_vat

Roughness Coefficient: 0.15

Impervious Ratio: 0.1

Green-ampt parameters

☒ Use soil depth layer

☐ Use constant value

Soil texture: GHG_SoilTexture

VAT file: C:/GRM/SampleGHG/watershed/GHG_SoilTexture_vat

Porosity: 0.43

Effective porosity: 0.43

Wetting front suction head: 0.30

Hydraulic conductivity: 0.38

Soil depth

☒ Use soil depth layer

☐ Use constant value

Soil depth: GHG_SoilDepth

VAT file: C:/GRM/SampleGHG/watershed/GHG_SoilDepth_vat

Soil depth: 0.38

GridValue	UserLandCover	GRMCode	roughnessCoeff	Imp
100	시가지/건조지역	URBN	0.015	0.01
200	농업지역	AGRL	0.035	0.31
300	산림지역	FRST	0.1	0.01
400	초지	GRSS	0.15	0.4

GridValue	UserSoil	GRMCode	Porosity	Eff
1	마사실식양토	SCL	0.471	0.43
2	마사실양토	SL	0.501	0.46
3	사양토	SL	0.453	0.41
4	사토	S	0.437	0.41
5	식양토	CL	0.464	0.30
6	식토	C	0.475	0.38

GridValue	UserDepthClass	GRMCode	SoilDepth
1	깊음	D	125
2	매우얕음	VS	10
3	보통	MDMS	75
4	얕음	S	25

OK Cancel

Setup land cover and soil data

Simulation GRM

Simulation

Watch points: Channel cross section

Flow control: Match point

Simulation environments

☒ Simulation time step: 10

☒ Simulation duration: 10

☒ Output time step: 10

Simulation options

☒ Infiltration

☒ Subsurface flow

☒ Parallel

Max degree of parallelism: 1

Output options

Print option: All

Make log file: ☒ Control rainfall

Make ASCII file: ☒ Show output

Save project & start simulation

OK Cancel

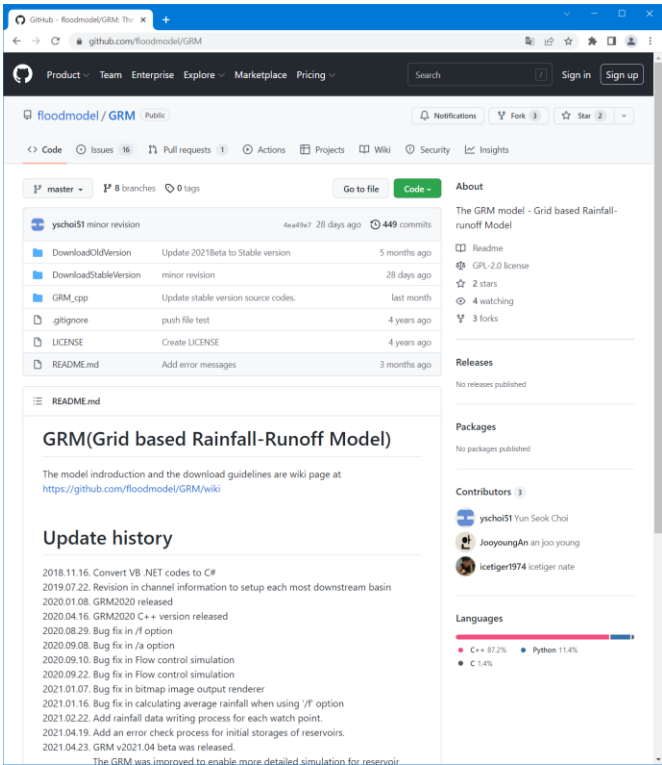
Model parameters setup

```
C:\Users\CYSW\python\plugins\GRM\DLL\GRM.exe
C:/GRM/SampleGHG/GRM500.gmp -> Model setup completed.
IsParallel : True, Max degree of parallelism : -1
Current progress: 51%.
```

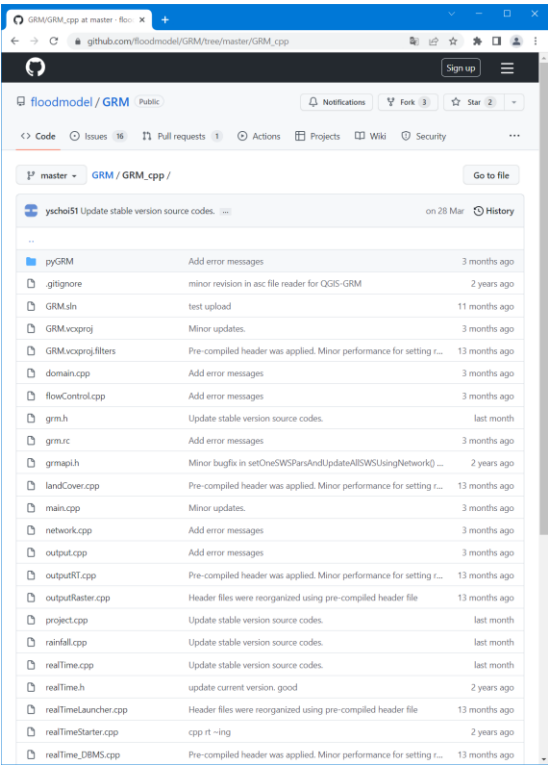
Run GRM

2. GRM 모델

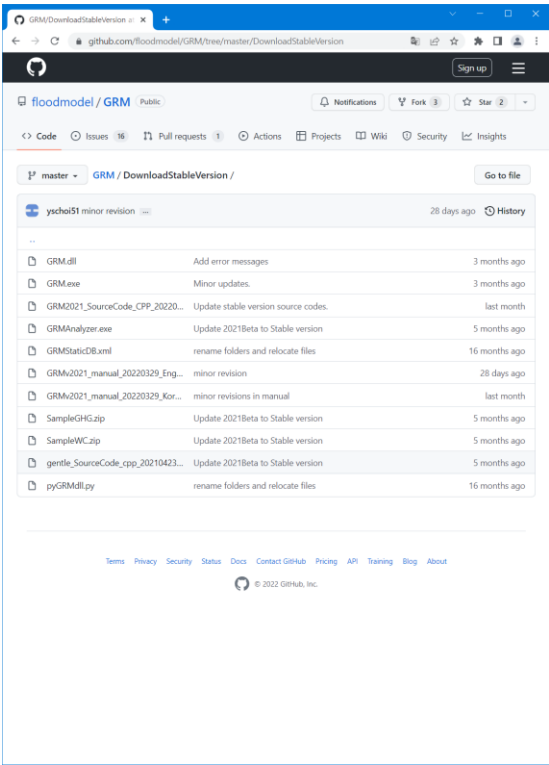
GRM Open source S/W (<https://github.com/floodmodel/GRM>)



G2D repository



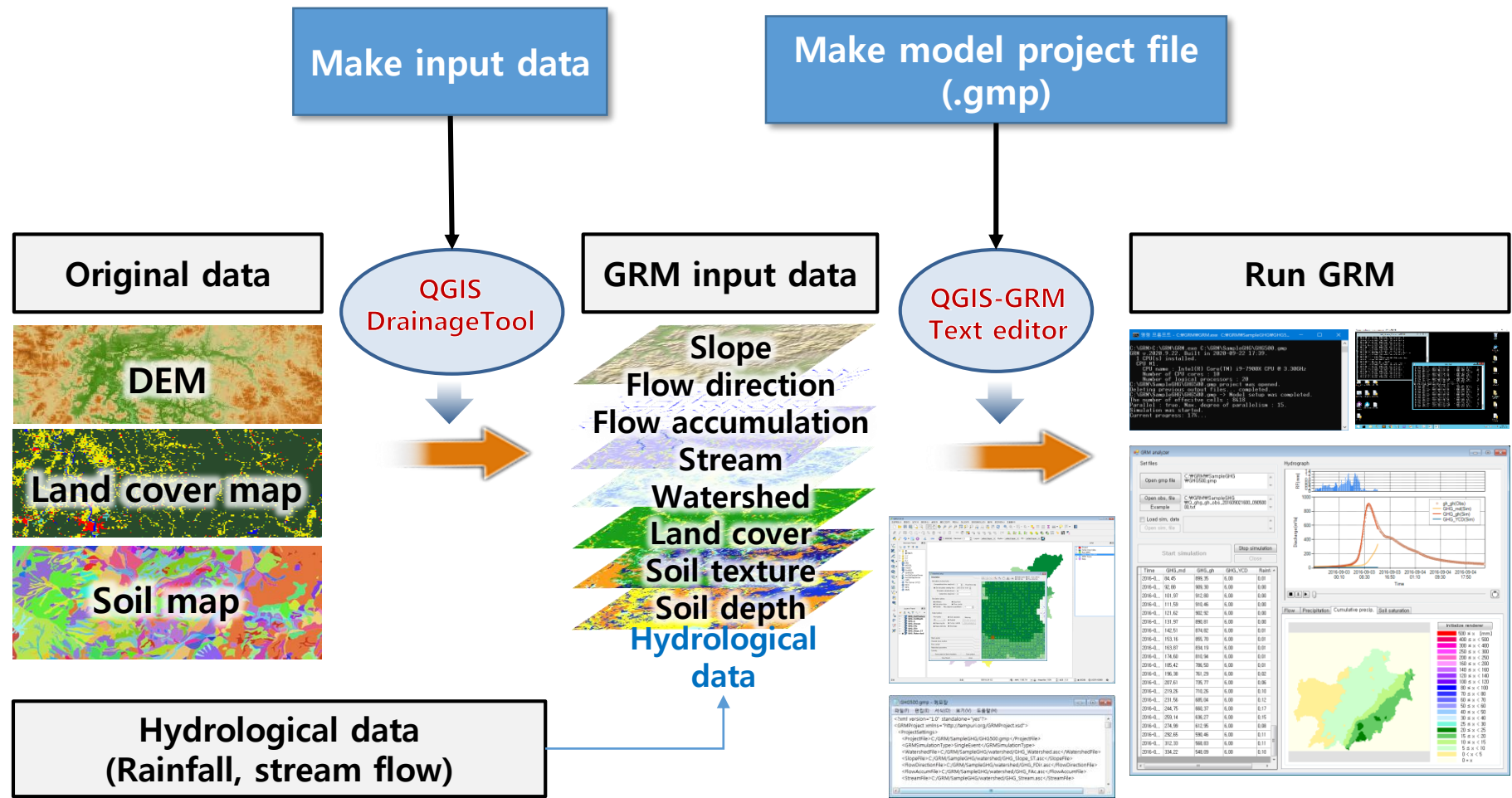
소스코드



실행파일, 매뉴얼, 샘플데이터

2. GRM 모델

활용절차

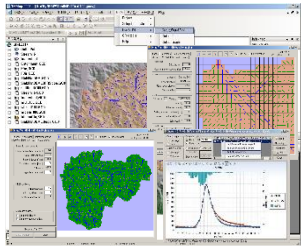


2. GRM 모델

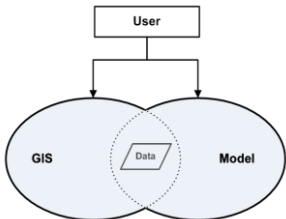
❑ S/W 관점에서의 고찰 (모델 개발 → 보급 확대 → 실무 활용 확대)

2007-2012

- Visual Basic .NET, 2008년 첫번째 버전 릴리즈
- 상용 S/W로 배포, HyGIS plug-in 으로 실행
- GIS에 embedded된 모델 (tight coupling)로 개발



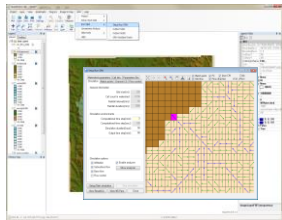
<GRM.dll + HyGIS>



< Integration, tight coupling >

2013 ~ 2016

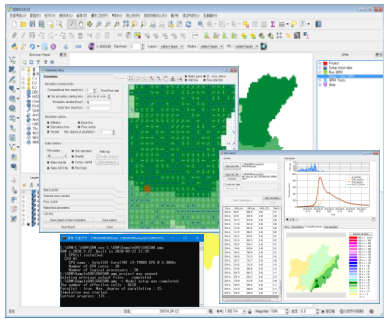
- Free S/W로 배포, Microsoft TFS 활용 팀 개발
- Open source S/W (OSS) MapWindow GIS의 plug-in 으로 실행



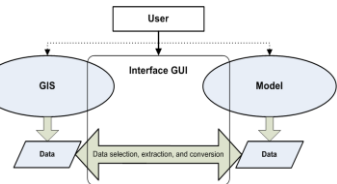
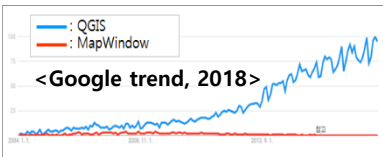
<GRM.dll + MapWindow>

2017 ~ 현재

- 오픈소스 S/W로 전환 (<http://github.com/floodmodel/GRM>)
- 모델에서 GIS와 GUI 분리, OSS QGIS(2.18.x, 3.x) 연계 (interface GUI 개발)
- CPU 병렬계산 기법 → 홍수예보 실무 적용을 위한 고해상도 고속 모델링
- 언어 변경 : VB .NET → ('17) C# (.NET Core, Linux)
⇒ ('20) C/C++ (Linux, 속도 향상)



<GRM.exe + QGIS>

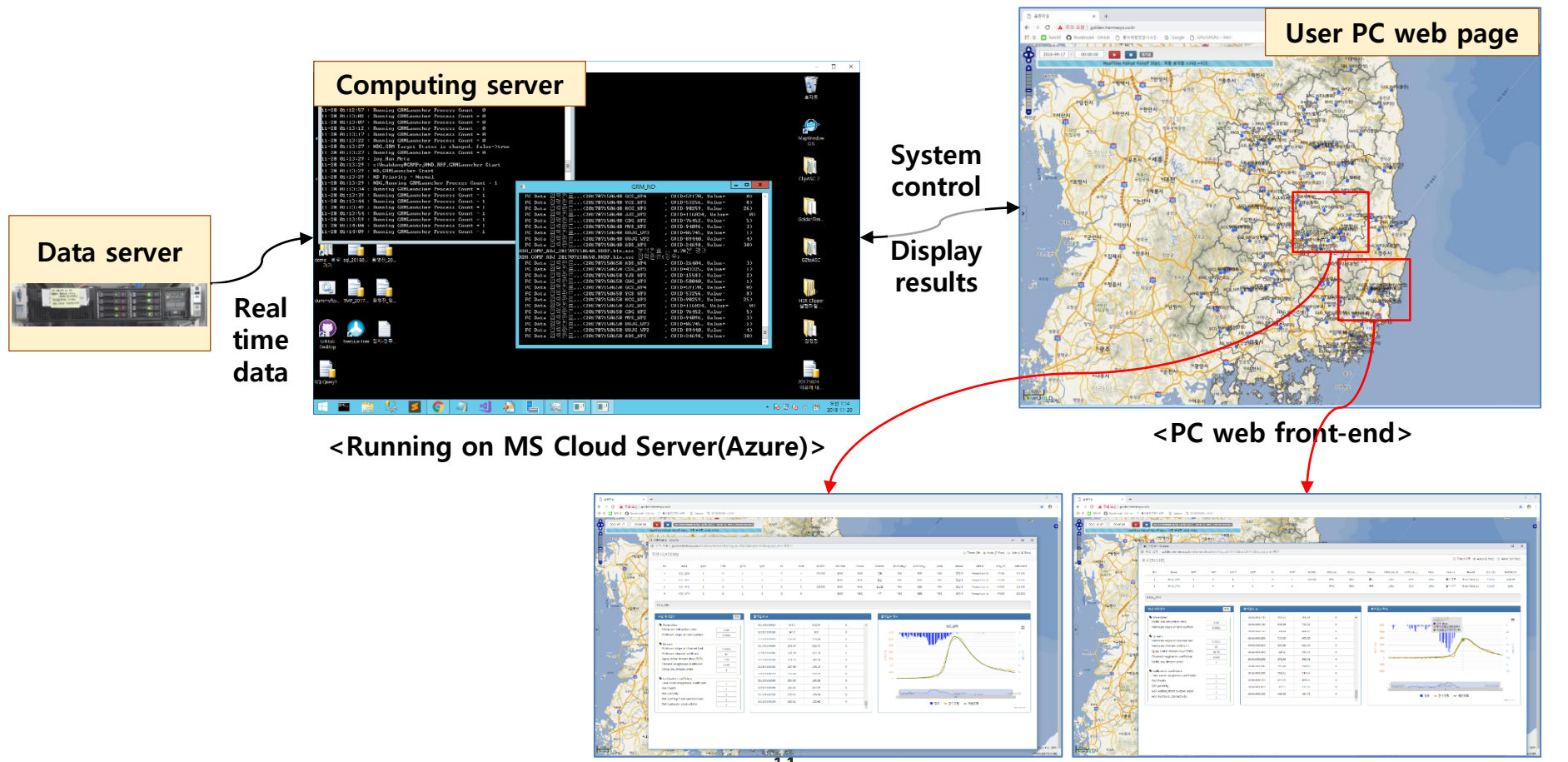


< Interface, loose coupling >

3. 적용사례

클라우드 서버와 연계한 실시간 홍수해석시스템

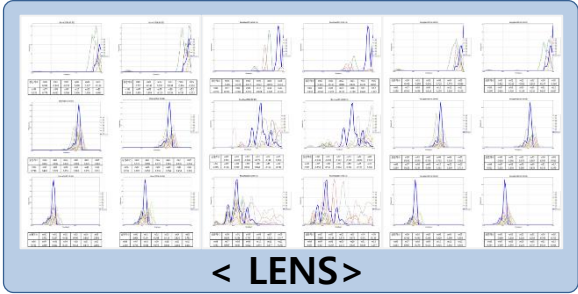
- 대상 지역 : 낙동강 유역
- 실시간 수문자료(자료 서버), 클라우드(계산서버), 웹(사용자)을 연계한 실시간 홍수해석시스템



3. 적용사례

전국 홍수유출 모의

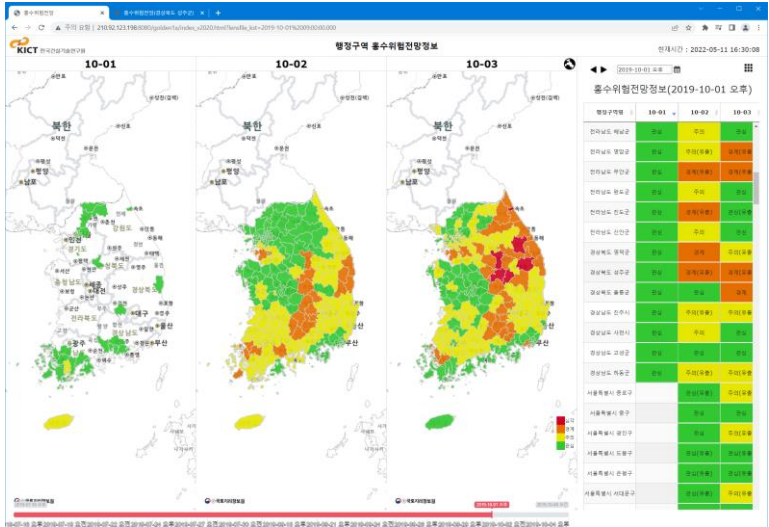
구분	골든타임 연구단 4세부	골든타임 연구단 2세부
대상지역	전국	전국
공간해상도	500m × 500m	250m × 250m
강우자료	기상청 국지앙상블시스템(LENS, Local Ensemble Prediction System)	환경부 강우레이더
활용분야	전국 기초지자체별 확률적 홍수위험전망	전국 하천 홍수예보



< LENS >



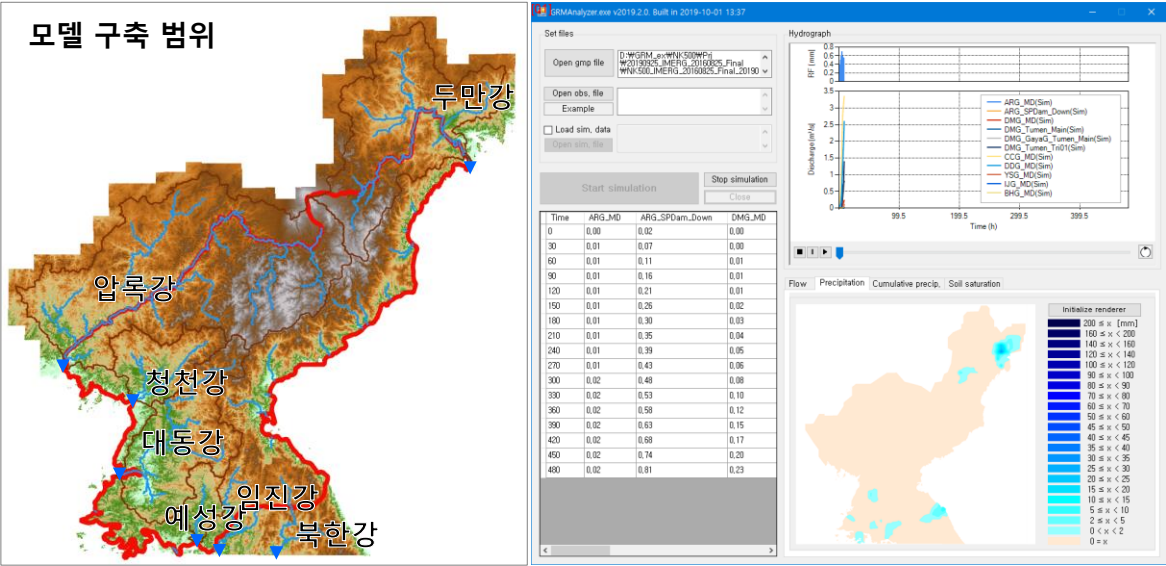
< GRM 유출모의 >



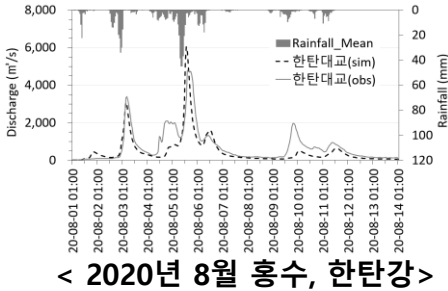
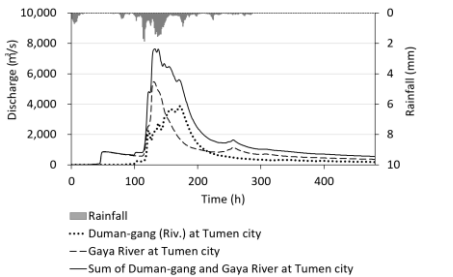
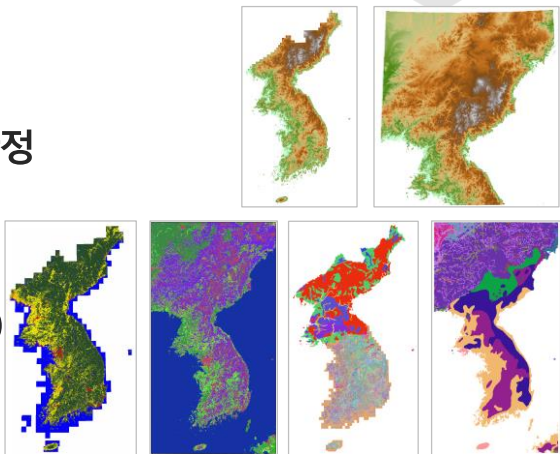
3. 적용사례

북한 지역 홍수유출 모의

- 북한 지역 전체에 대한 홍수유출 해석 모델 구축 → 북한 임의 지점 유량 산정
- 공간자료 : 북한, 중국, 러시아 지역 자료 병합, 500m × 500m 해상도,
(원시자료 : 국토지리정보원 DEM, SRTM DEM, 환경부 토지피복도, Global Map 토지피복도, 농업과학원 정밀토양도/한국농업기본도, HWSD 토양도)
- 강우자료 : 위성으로부터 유도된 강우



- 북한 영역
- 유역 경계
- 하천망
- ▶ : 대하천 최하류 지점



감 사 합 니 다 .



○ 감사의 글

본 연구는 환경부의 재원으로 한국환경산업기술원의 물관리연구사업의 지원을 받아 연구되었습니다[2019002640014].

○ 주요 관련 과제

- 골든타임 확보를 위한 유역 시공간 상세 홍수예보기술 개발 (한국환경산업기술원, '17~'22)
- 위성자료를 이용한 북한 홍수범람 분석기술 개발 (한국건설기술연구원, '18~'20)
- 수문레이더 기반 홍수·폭설재해 예측 및 경보 플랫폼 개발 (한국건설기술연구원, '13~'17)
- 수자원의 지속적 확보기술개발 사업 (교육과학기술부, '02~'11)