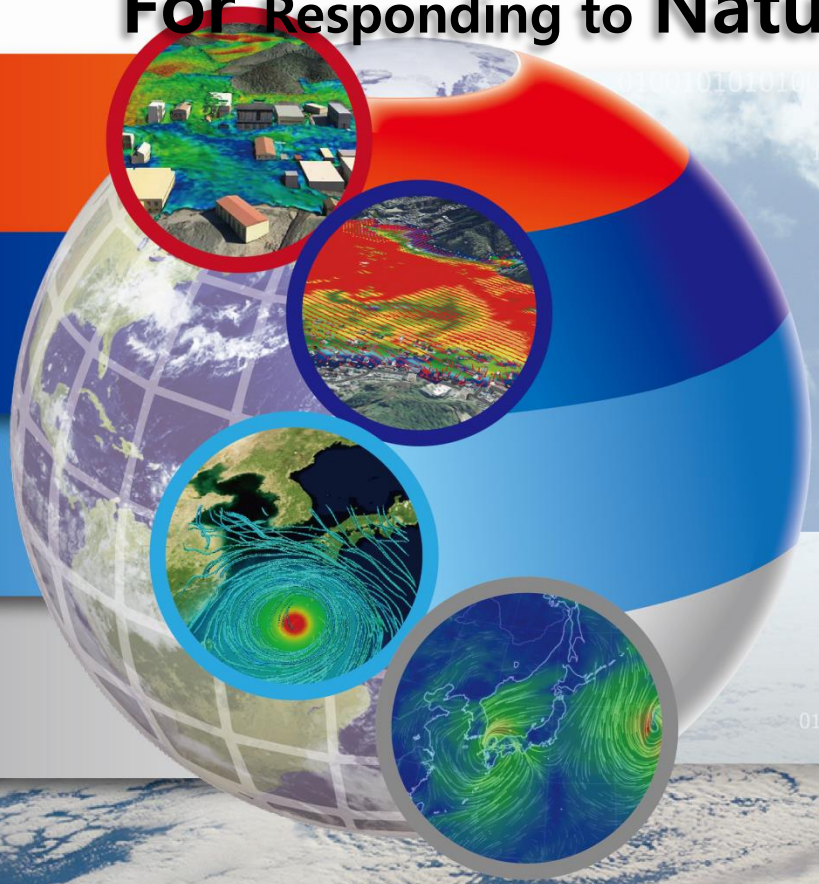
Development of A Decision-Making Support System For Responding to Natural Disasters



Minsu Joh

Ph.D. in Atmospheric Science
Director of Disaster R&D Center

KiSTi www.kisti.re.kr Korea Institute of Science and Technology Information

Contents

Government supported
Research Institute
(Since January,1962~)

The National
Supercomputing Center
(On September, 2012)

Personnel : ~ 380
Annual revenue : ~ 120M$
Location : Daejeon

KiSTi www.kisti.re.kr

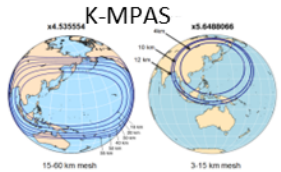
Overview of K-DMSS

- Integrated
  S/W Package for Predicting Disasters & Damage Assessment
- Developed on
  HPC (high performance computing) & Big Data Platforms
- Supports for High resolution
  Modeling & Simulation for Atmosphere-Ocean & Hydrology
- Supports for Huge data
  Visualization & AR (augmented reality) for Scientific Analysis
- KISTI's independent
  Decision-Making Support System for Disaster Management

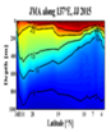
Components of K-DMSS

K-DMSS : Software system

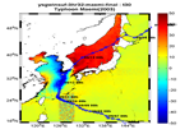
A High Resolution M&S



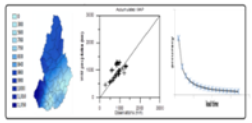
High Resolution Weather prediction



Surge Prediction

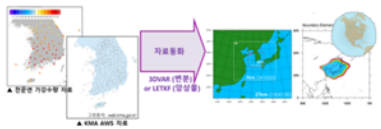


Tide Surge Prediction



River Flooding Prediction

Data Assimilation



Predicable water, AWS 등

B Disaster Information System

Web Portal Service

Data Register/Search

Scenario Operation

Data Storage

Disaster Information Management

Data Exchange

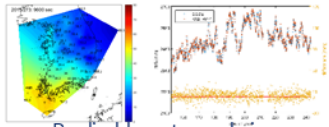
C Data Collection/ Information Extraction

Sensors, WWW, Open API, SNS

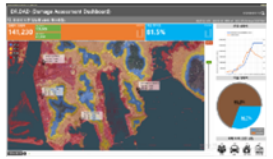
Big Data Analysis

Knowledge Detection Framework

D Analysis System

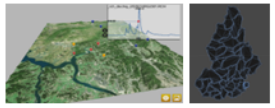


Predicable water analysis system Based on GNSS

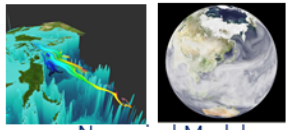


Disaster Prediction & Damage Assessment System

Visualization System



3-Dimensional Integrated Visualization System



Numerical Model Visualization System

HPC Testbed

OpenMP Fortran MPAS Model for Prediction Across Scales OpenACC More Science, Less Programming VAPOR Visualization & Analysis Platform

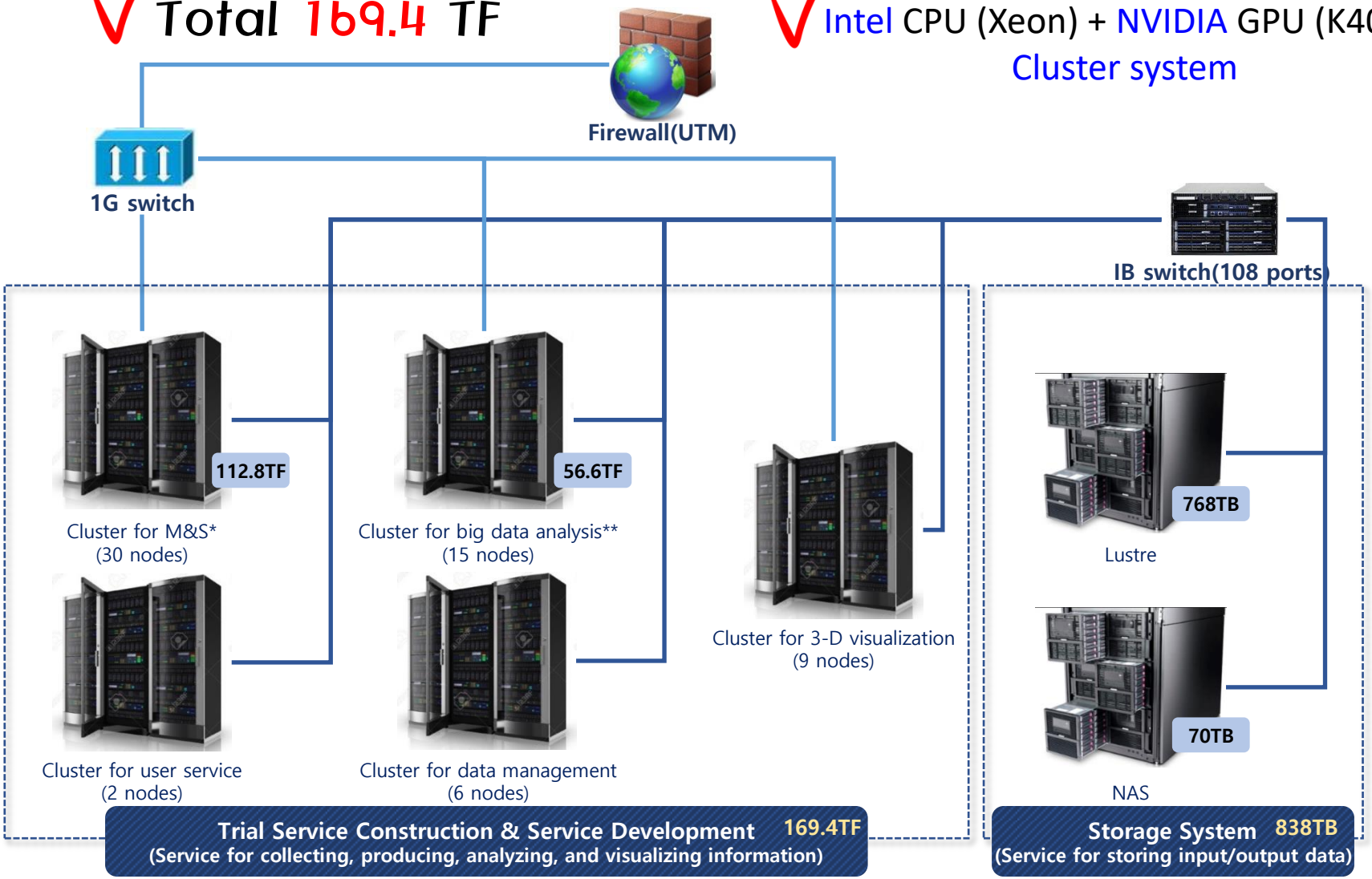
hadoop Spark NotOnlySQL TensorFlow NVIDIA CUDA

Big Data Testbed

HPC & Big Data Testbed

√ Total 169.4 TF

√ Intel CPU (Xeon) + NVIDIA GPU (K40M) Cluster system



* **Cluster for M&S:** 30 nodes(CPU+GPU), 12TF + 100.8TF = 112.8TF / 600 cores + (172,800 cores) = 173,400 cores

** **Cluster for big data analysis:** 15 nodes(CPU+GPU), 6.2TF + 50.4TF = 56.6TF / 300 cores + (86,400 cores) = 86,700 cores

High Resolution Modeling & Simulation

- International Collaboration with NCAR/MMM
  Development of K-MPAS & Kr-MPAS based on MPAS
  South Korea is located in the middle

- KISTI's independent
  Development of EDAS for K-MPAS based on LETKF
  Ensemble Data Assimilation System Local Ensemble Transform Kalman Filter

- KISTI's independent
  Development of GPU Acceleration Code of MPAS (Physics Part)
  OpenACC (2017) → CUDA (2018)
  NCAR developed MPAS GPU code (Dynamic Part)

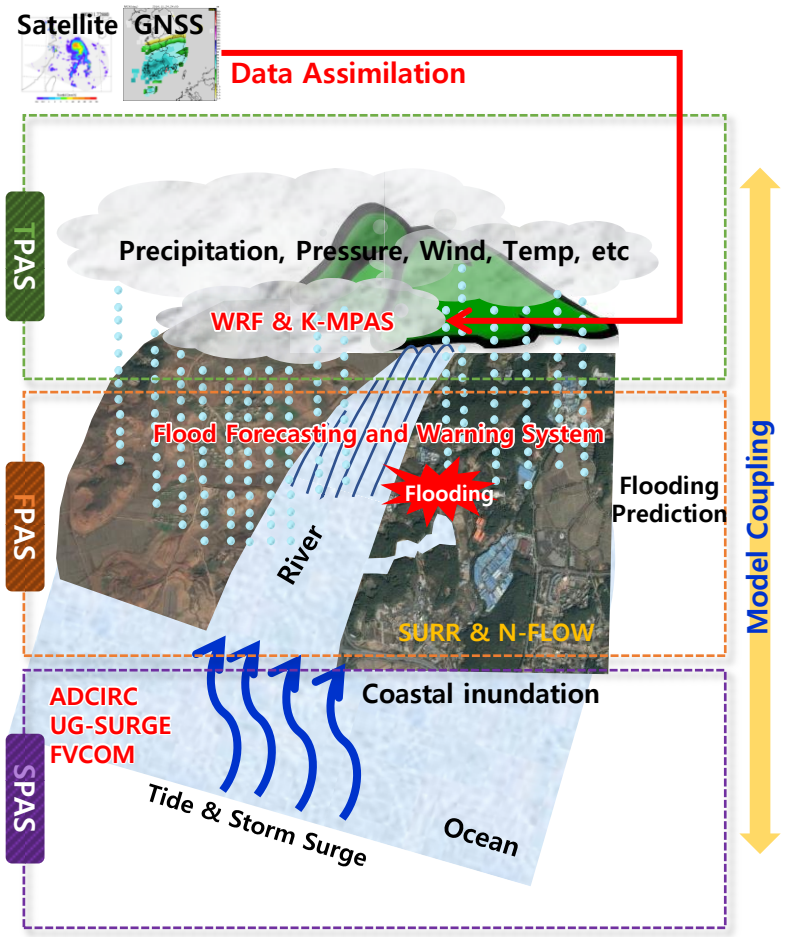
- **Development of Integrated Prediction System of W-O-W models**
  Weather-Ocean-Water
  (WRF/K-MPAS) – (ADCIRC/FVCOM) – (SURR)

- **Simulation of Typhoon-Surge-Flood for specific regions**
  Weather-Ocean-Water The Imjin River, Busan City, etc.

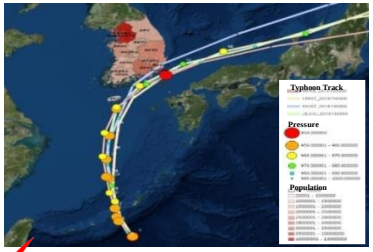
MPAS = Model for Prediction Across Scales | K-MPAS = KISTI MPAS focused on Typhoon Prediction

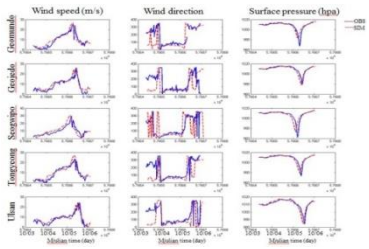
Prediction & Analysis Systems

High Resolution Coupled Modeling System Based on HPC



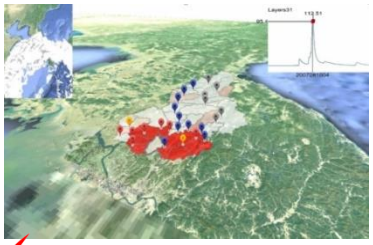
T TPAS (Typhoon Prediction and Analysis System)



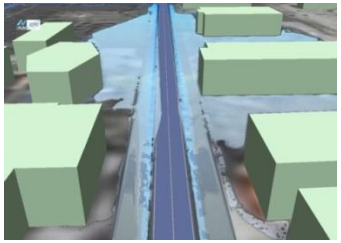


WRF & K-MPAS : Weather Prediction

F FPAS (Flood Prediction and Analysis System)

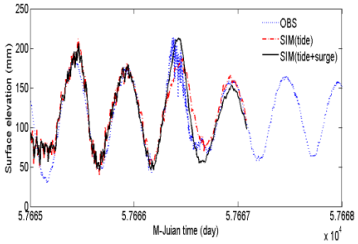


SURR : Flood Prediction

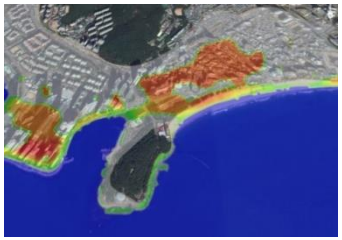


N-FLOW – SPH Modeling

S SPAS (Surge Prediction and Analysis System)



FVCOM : Surge Prediction

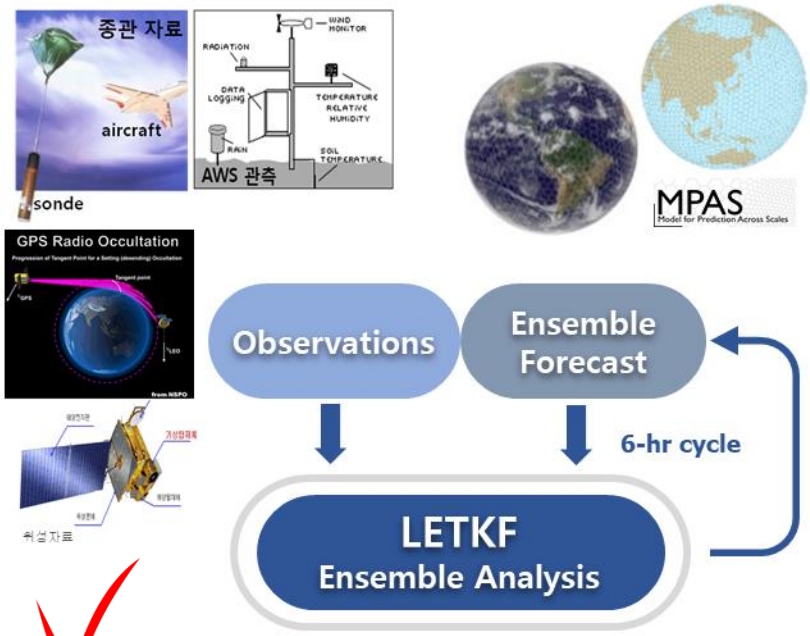


Coastal Inundation

Prediction & Analysis Systems

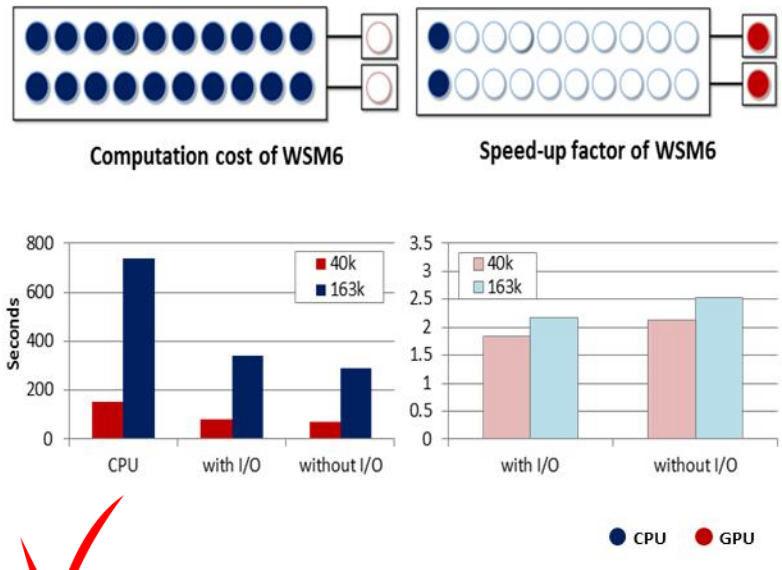
A

MPAS Ensemble Data Assimilation System



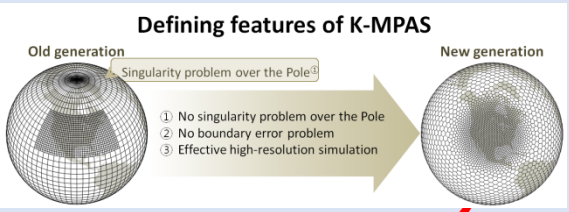
Increasing Accuracy of Prediction

CPU-GPU Heterogeneous code of MPAS



Increasing Speed of Simulation

Defining features of K-MPAS

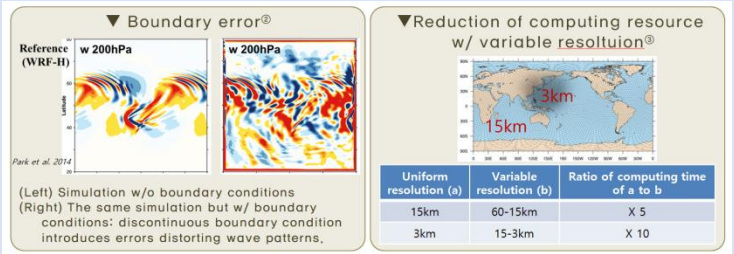


Comparison of track errors among three NWP models

MPAS(60-15km), UM(N768, ~17km in mid-lat), ECMWF(T1279, ~16km)

Fcst hr	# of cases	MPAS	UM	ECMWF
24	60	67.6	80.3	68.4
48	44	110.9	148.0	112.8
72	32	182.1	269.2	224.1
96	21	214.6	364.7	279.6
120	14	272.5	432.5	374.7

(For the 1st ~ 18th typhoon in 2016, data collected till 20161004UTC)



K-MPAS is developed
Under the KISTI-NCAR international
Collaboration Project (2014~2017)

Comparison of Typhoon track errors
done by KMA (18 typhoons in 2016)

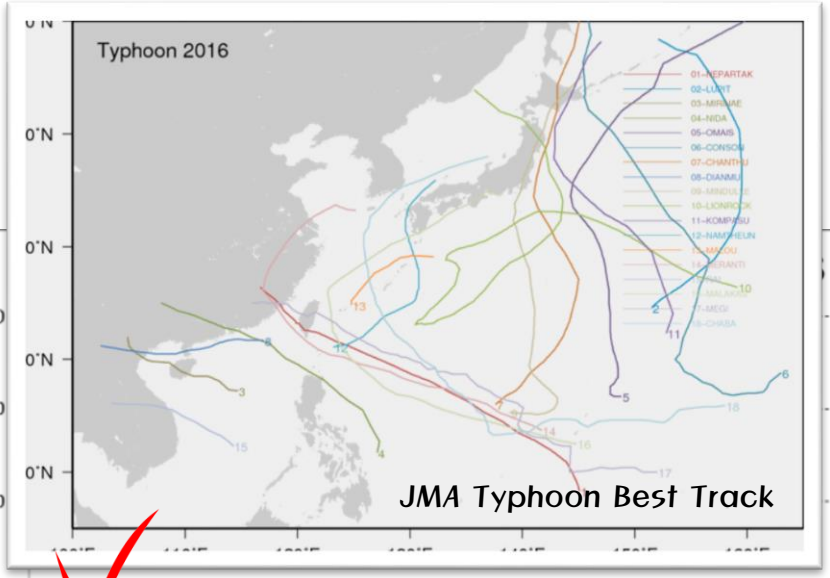
Best Better Good

K-MPAS > ECMWF > UM

24h, 48h, 72h, 96h, 120h (forecast hours)

Prediction & Analysis Systems

A

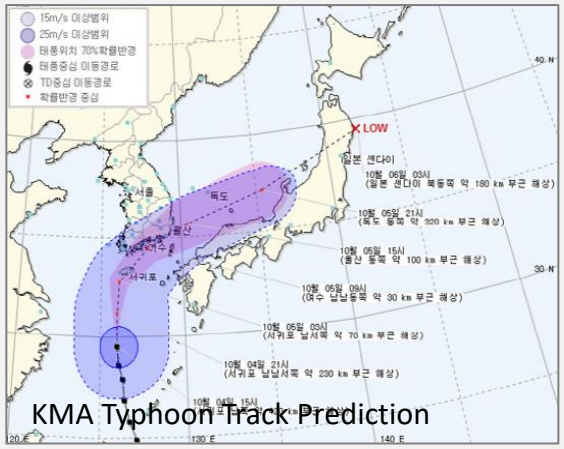


K-MPAS

Typhoon Track Prediction in 2016

CHABA

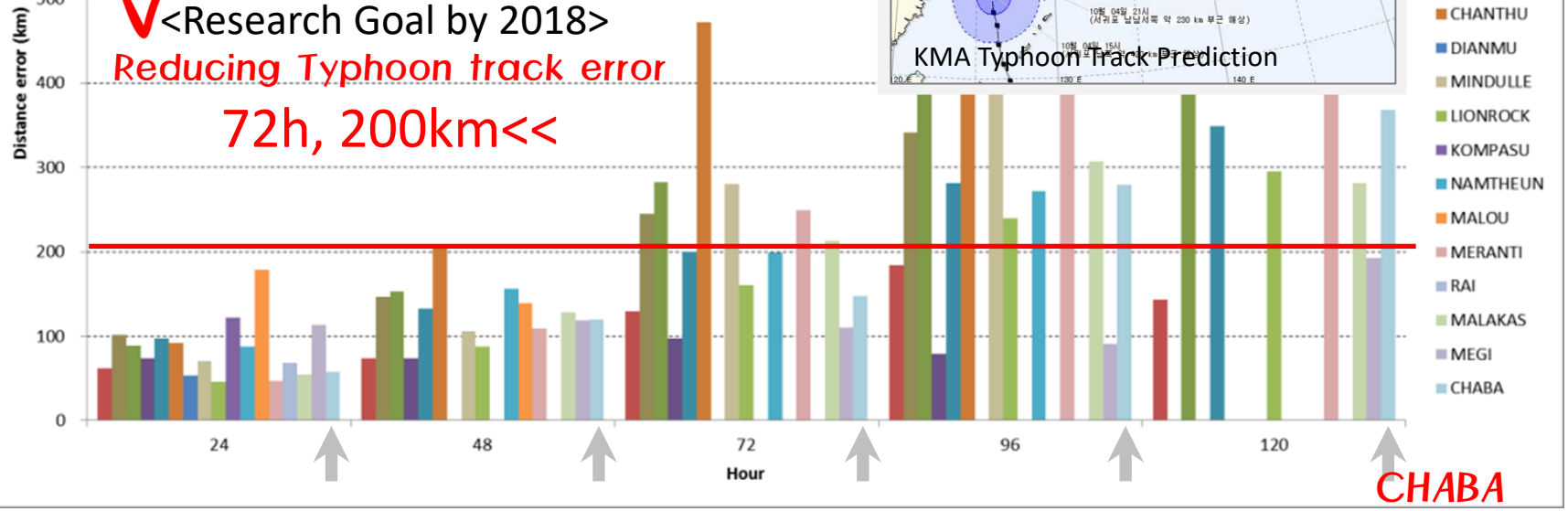
Typhoon influence on the Korean Peninsula



<Research Goal by 2018>

Reducing Typhoon track error

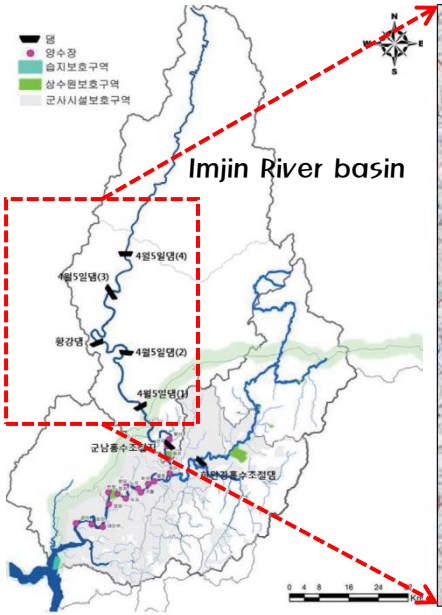
72h, 200km<<



Prediction & Analysis Systems

A

Flood prediction system with the Hydraulic structure in North Korea

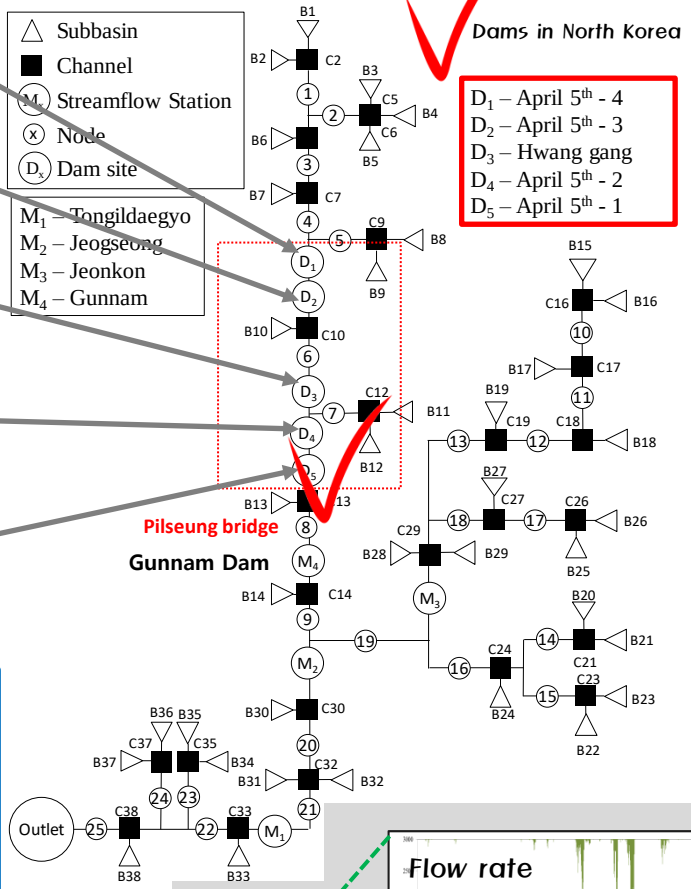


△ Subbasin
■ Channel
Ⓜx Streamflow Station
ⓧ Node
Dx Dam site

M_1 – Tongildaegyo
M_2 – Jeogseong
M_3 – Jeonkon
M_4 – Gunnam

Dams in North Korea

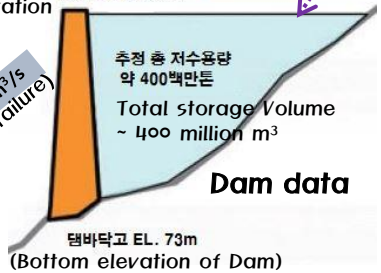
D_1 – April 5th - 4
D_2 – April 5th - 3
D_3 – Hwang gang
D_4 – April 5th - 2
D_5 – April 5th - 1



EL. 105.8 m
(Maximum Flood elevation)

Hwanggang dam
황강댐

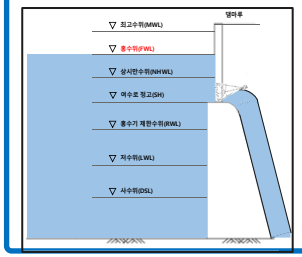
Dam crest elevation
댐정고 EL. 107m

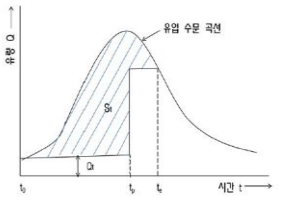


댐 붕괴시
16,4467 m³/s
(Dam failure)

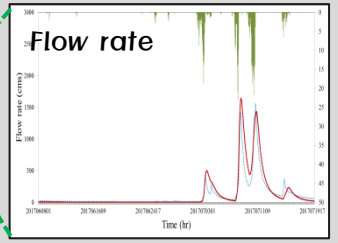
Auto ROM

(Dam operation when dam water level reaches the designed water level)





Pilseung bridge 8



Disaster Information System

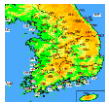
DIS is the integrated information system which has several features including

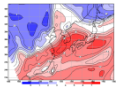
- **Data Management & Search based on Standard Metadata**
  Such as GNSS data from KASI
- **Metadata Harvesting from External Information Sources**
- **Open API to share Disaster Information**
- **High Scalability in Computing Power and Data Storage**
- **Workflow Environment for Creating Integrated Scenarios**
  Such as Military Weather Scenario, Flood Scenario

Architecture of DIS

B

Observation Data


AWS Data


GNSS Data


Satellite Image


Ocean Observation Data


River Waterlevel Data


GIS Data

Scenario Operation

Scenario Generation
- Workflow Generation & Management

Scenario Monitoring
- Real-time Workflow Monitoring

Process Registration
- Workflow Action Registration

Statistics Service
- Analysis of Scenario Use

Data Management

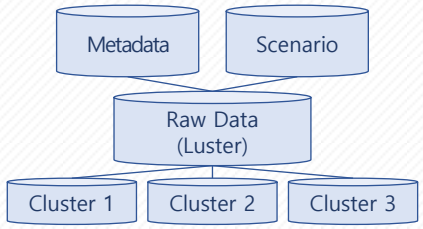
Data Collection
- Observation/Prediction Data Collection
- Standard Metadata Registration

Data Search
- Metadata Search
- Open-API

Data Processing
- Data Compression/ Decompression
- Data Movement/ Format Conversion

Data Exchange
- Metadata Exchange (OAI-PMH)
- Observation/Prediction Data Distribution

Data Storage



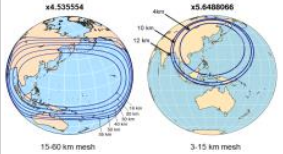
Metadata/Raw Data Storage

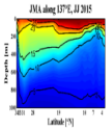
Scenario Storage

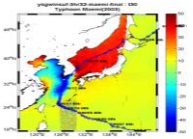
Cluster-based File System for Massive Data

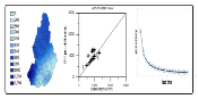
Prediction Data

K-MPAS


Weather Prediction


Surge Prediction


Tide Surge Prediction

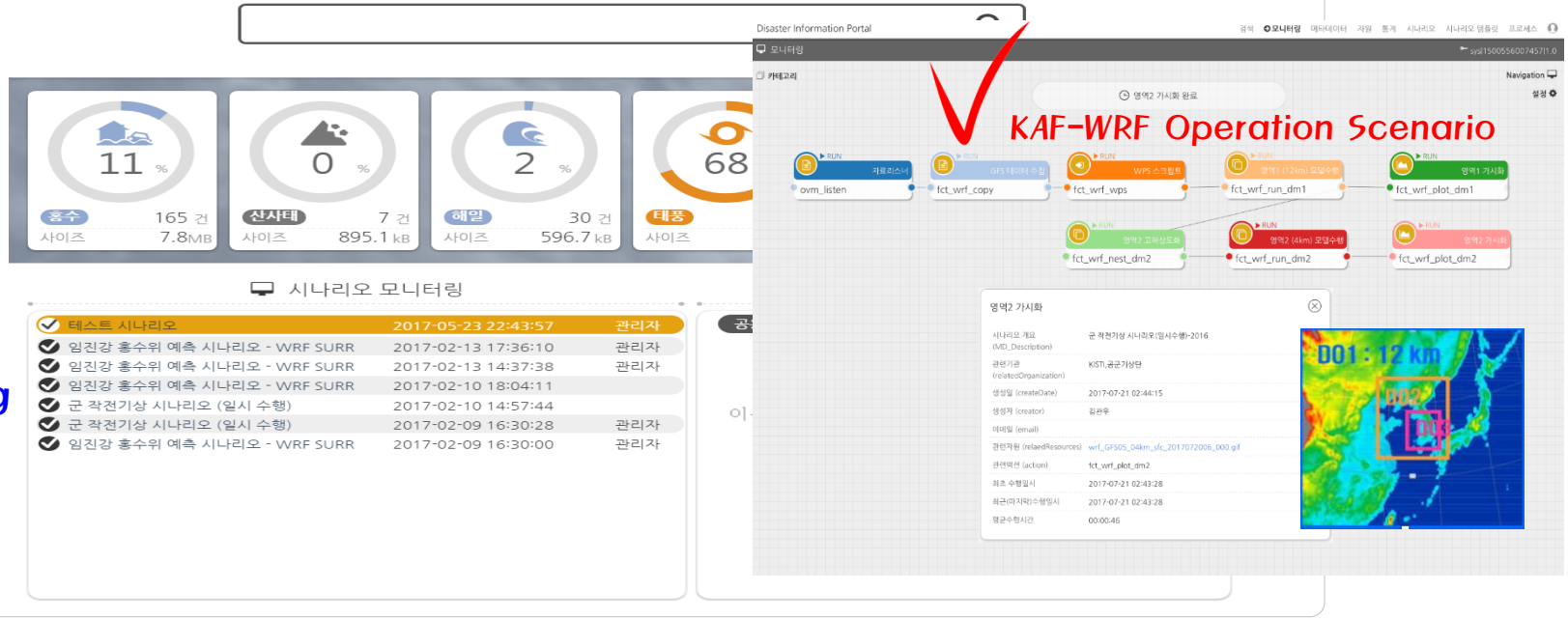

River Flooding Prediction


Damage Prediction

DIS Web Portal

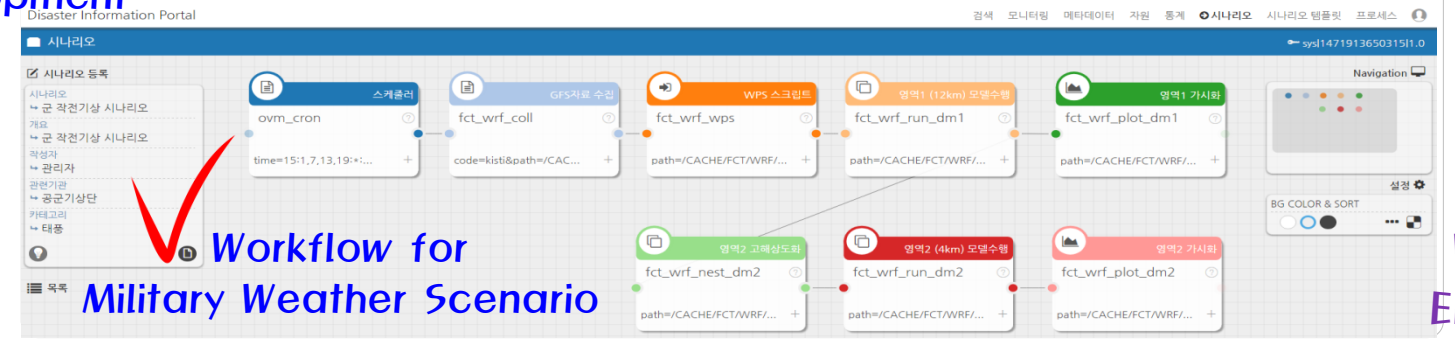
▼ Disaster Information Web Portal (Main Page)

Scenario Monitoring Page



Scenario Development Page

▼ Disaster Information Web Portal (Scenario Page)



Workflow for Military Weather Scenario

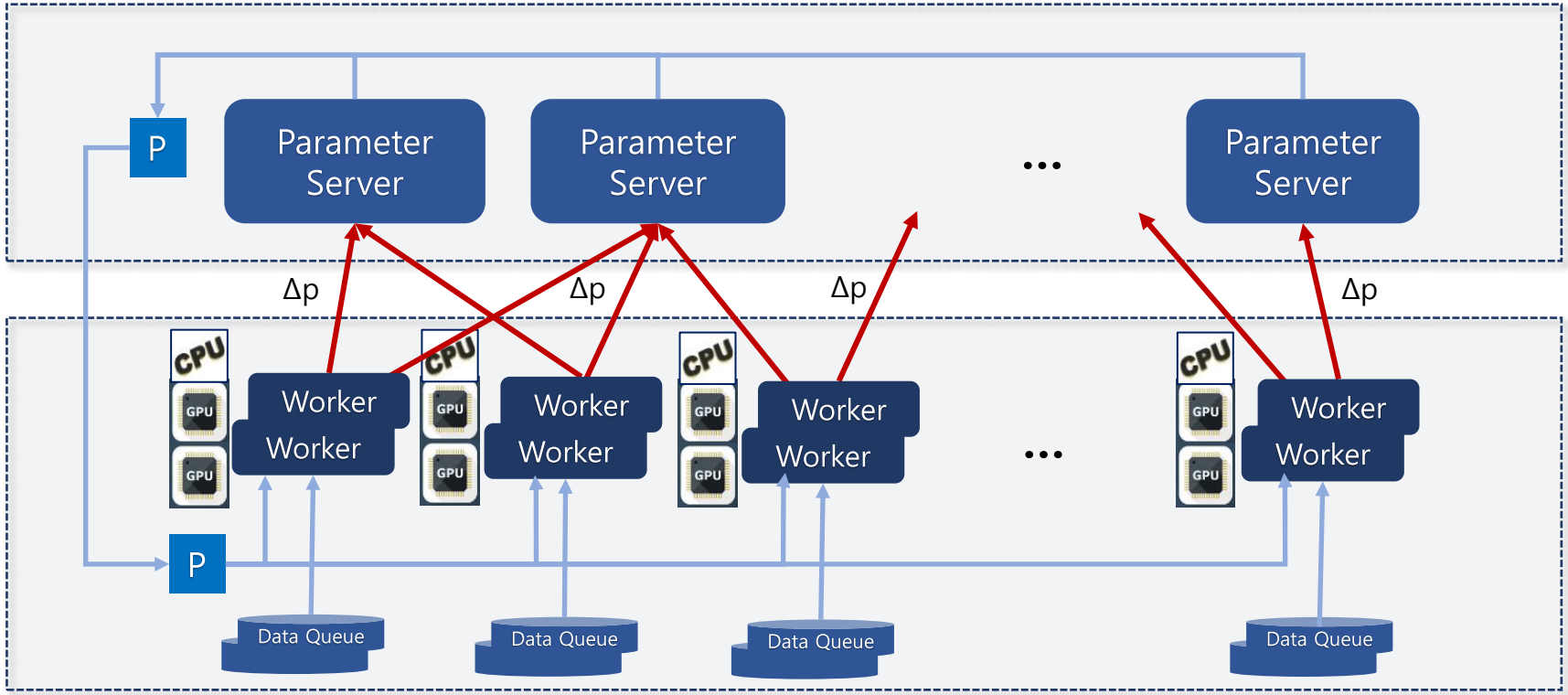
Workflow Environment

Disaster Knowledge Detection

R& D for DKD have been doing since 2015 based on the Big Data Platform.

- **Predicting Disaster Intensity & Damage Extent**
  By Big Data Analysis
- **Developing Specialized Deep Learning Algorithms**
  For Disaster Detection
- **Applying Recent Deep Learning Algorithms**
  Such as CNN/RNN, convLSTM
- **Developing Distributed Deep Learning Platform**
  Supporting for very large data set
- **Developing Docker/Kubernetes-based Platform**
  To ensure data scalability

KISTI Deep Learning Platform



Big Data Testbed

Cluster for big data analysis** (15 nodes)

Spark · Spark Streaming · TensorFlow · NVIDIA CUDA · hadoop · NotOnlySQL · kubernetes by Google · docker

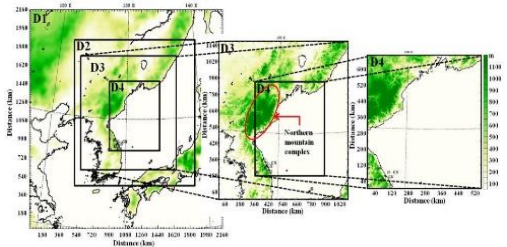
* Cluster for M&S: 30 nodes(CPU+GPU), 12TF + 100.8TF = 112.8TF / 600 cores + (172,800 cores) = 173,400 cores

** **Cluster for big data analysis: 15 nodes(CPU+GPU), 6.2TF + 50.4TF = 56.6TF / 300 cores + (86,400 cores) = 86,700 cores**

KISTI Deep Learning Model

Input Data → Output Data

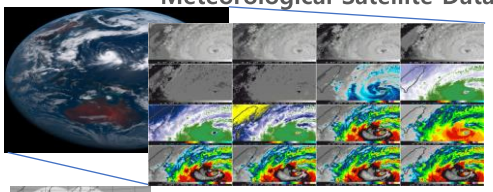
WRF Simulation Data

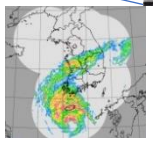


Various WRF Simulation Data & Predicted Typhoon Data

Observation Data

Meteorological Satellite Data



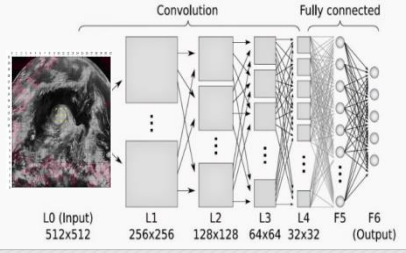


Radar Data

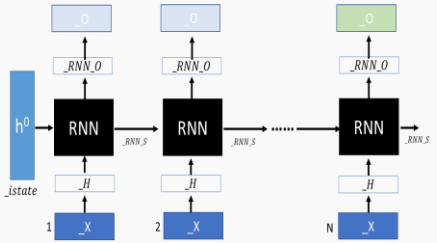
Sensor Data

Deep Learning Model

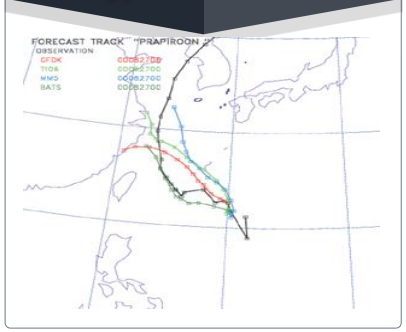
Convolution Neural Network



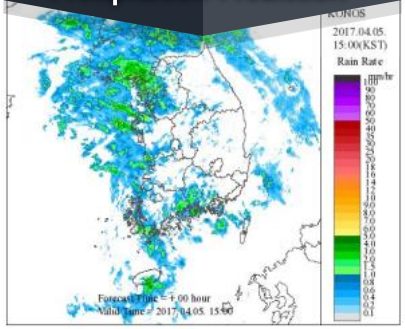
Recurrent Neural Network

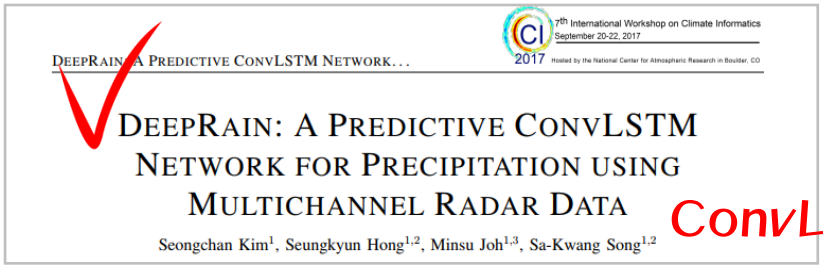


Typhoon Prediction

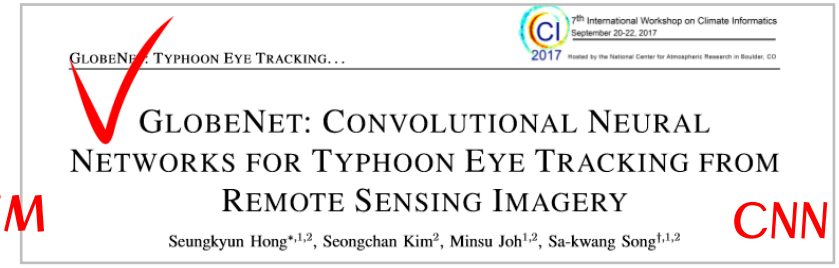


Precipitation Prediction





ConvLSTM



CNN

Selected as one of top papers by CI organizing committee (Sept. 4, 2017)

Disaster Damage Assessment

DDA system has several features including

- **Direct Damage Prediction** by Statistical Approach
  Facility Damage
- **Indirect Damage Prediction** using Big Data Analysis Techniques
  Business Damage
- **Web-based GIS system** for Vis. of Direct/Indirect Damage
- Prediction Output Provisioning with Open API
- Observed, Predicted & Analyzed Data Convergence

Damage Prediction System

Observation / Prediction Data

- Text Extraction Damage Data
- Numerical Damage Data
- Historical Weather Data
- Topography/ Buildings / Facilities / Environment Data
- Weather Forecast Data
- Flood Stage Data
- Flood/Inundation Prediction Data
- ...

Facility (Direct) Damage Prediction Model

- Statistical Prediction of Damage
- Facilities(Direct) Damage Prediction
- Quantitative Damage Assessment

Business (Indirect) Damage Prediction Model

- Floating Population + Location Info. + Sales Transaction
- Disaster History + Business Type/ Sales Effect Based on Text
- Days Sales Estimation
- Event Based Sales Estimation
- Local Vulnerability
- Unit/Regional Sales Damage

Web-based GIS system for Visualization

- Building or Reginal Economic Damage Visualization
- Providing Economic Damage Shapefile for GIS S/W
- Indication of Damage According to Risk Level

Big Data Platform

- Real-Time Streaming Big Data Framework (Apache Spark, Spark Streaming)
- Hadoop Ecosystem Based Big Data Framework (Apache Hadoop Ecosystem)
- Machine Learning Framework (MLlib, TensorFlow, Theano, Caffe)
- GPU-Accelerated Parallel Processing Framework (GPGPU, Multi-GPU)

Achievements & Plans

KiSTi www.kisti.re.kr

K-DMSS (KISTI-Decision Making Support System)

System Delivery In 2017~2018

Korean Airforce Weather Wing

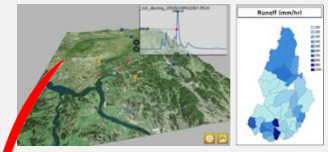
Military Weather Info. Service

K-DMSS Subsystems & Models

- TPAS (Typhoon Prediction and Analysis System)
- FPAS (Flood Prediction and Analysis System)
- SPAS (Surge Prediction and Analysis System)
- EDAS (Ensemble Data Assimilation System)
- K-MPAS CPU-GPU Hybrid Weather Prediction Model
- DIPAS (Direct damage Prediction & Analysis System)
- IPAS (Indirect damage Prediction & Analysis System)
- Deep Learning Typhoon Track Prediction Model
- Disaster Information Integrated System
- Disaster Information Portal System
- 3D integrated Visualization System
- Numerical Model Visualization System

Deliverable in 2017

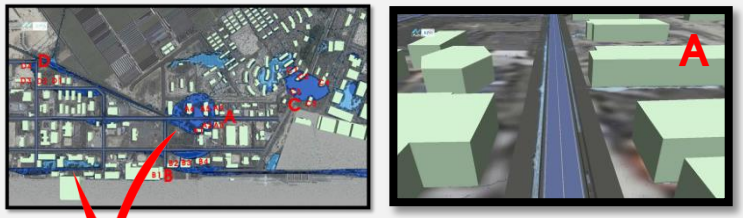
Military Operation Scenario in the South Korea



Flood Prediction Scenario on the Imjin River

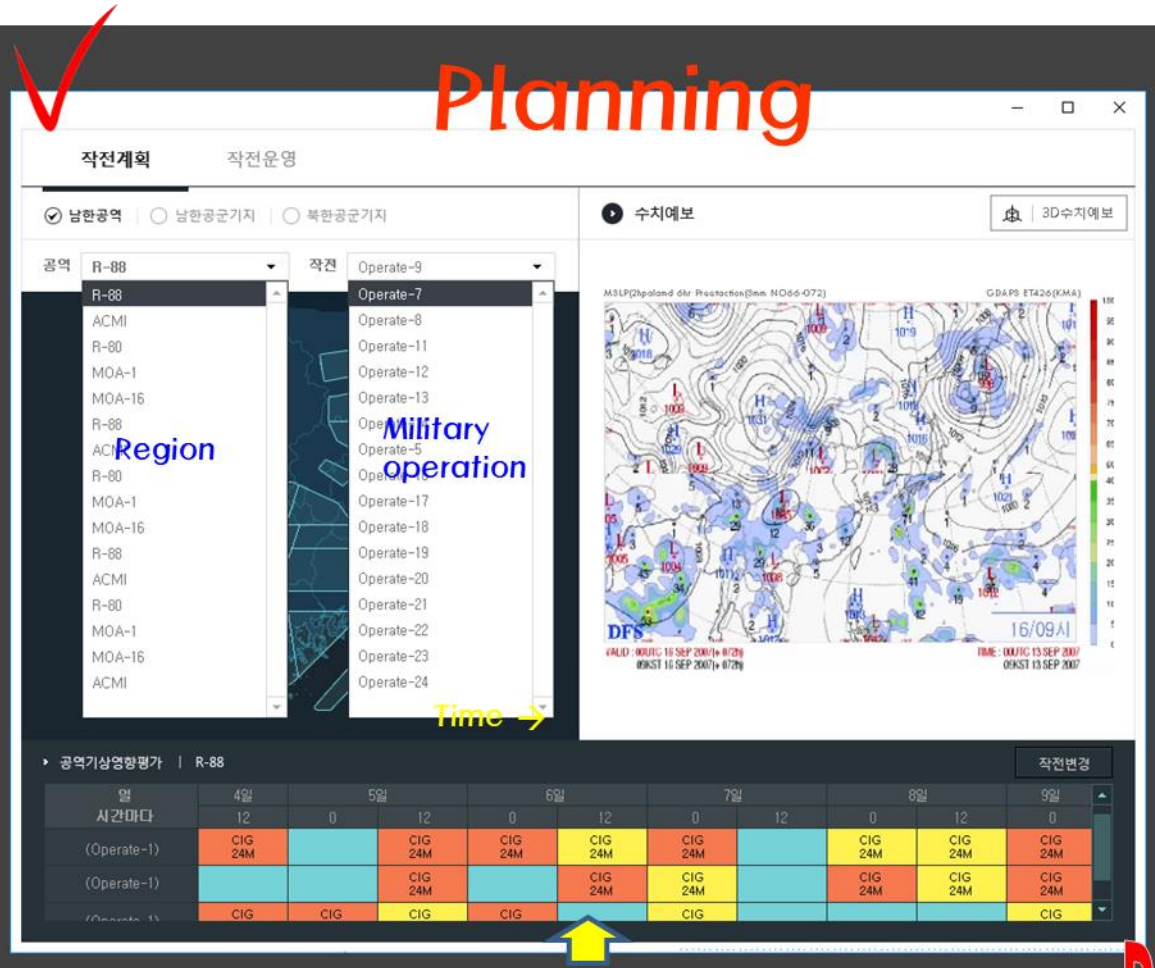
- 3D integrated Visualization System
- Numerical Model Visualization System
- FPAS (Flood Prediction and Analysis System)
- Disaster Information Integrated System

Deliverable in 2018



Flood Prediction Scenario at the KAF airbases

Military Operation Scenario



High resolution Numerical Weather Forecast Result

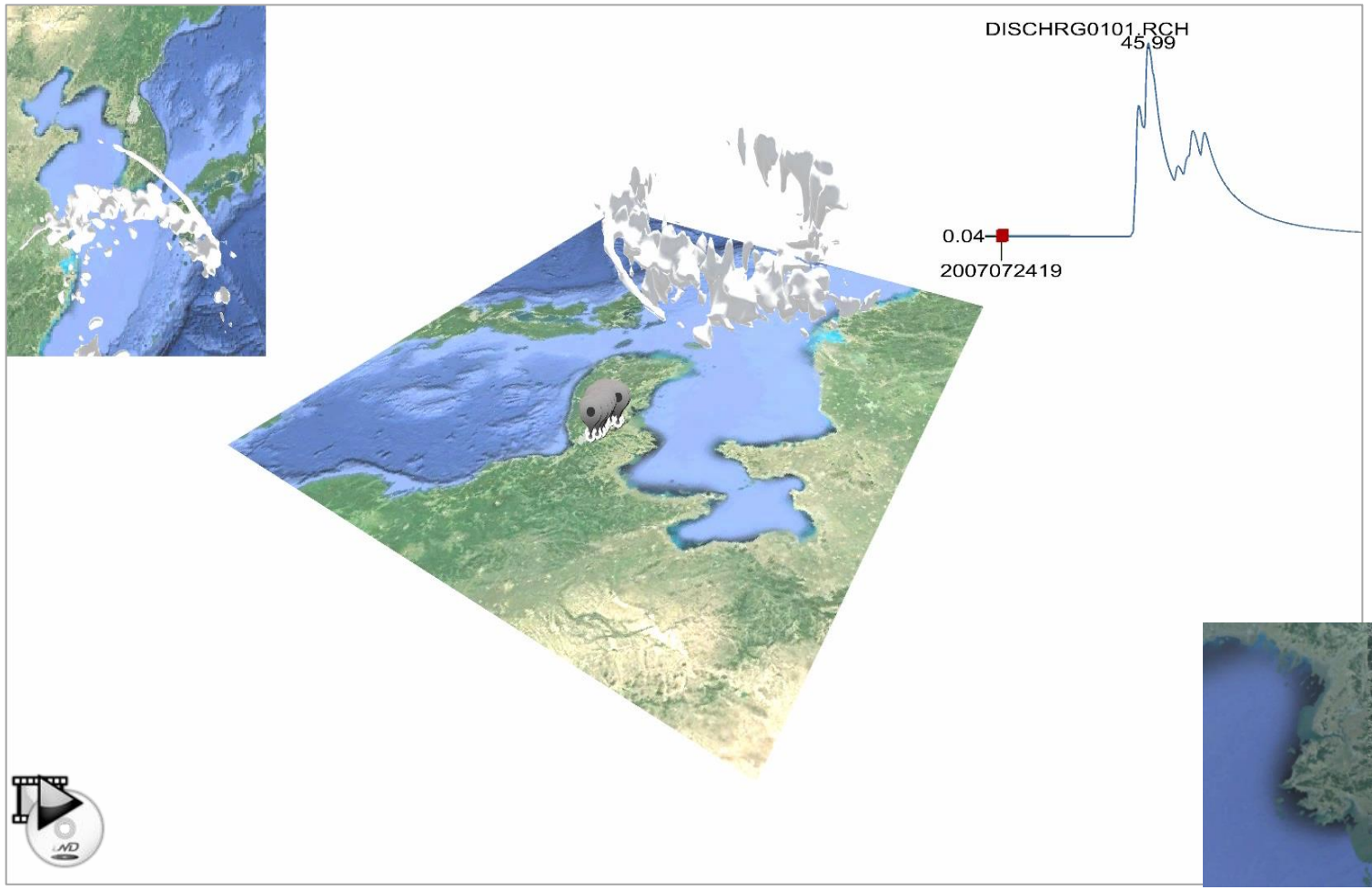
HPC

Scenario-based Weather Assessment Result

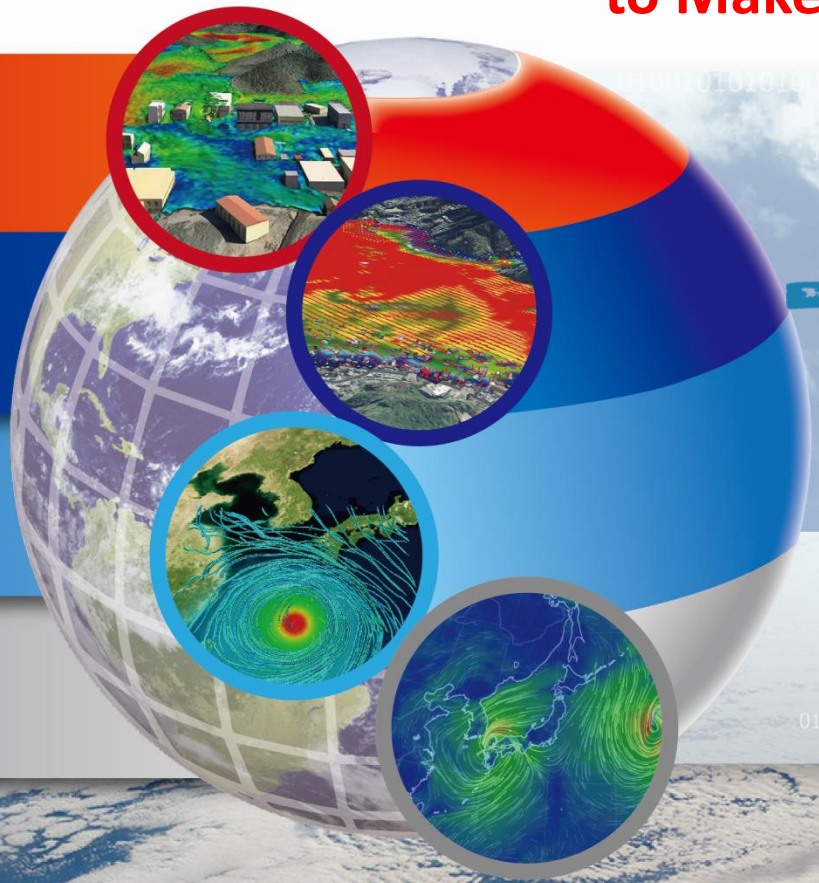
BIG DATA

Flood Prediction Scenario

Obs. Data	DA	Typhoon	Surge	Flood	SV
As-Is	PWV	3DVAR	K-WRF	UG-SURGE	SURR
To-Be	+ Etc.	LETKF	Kr-MPAS		



To Provide the Right Information
to the Right People, at the Right Time,
to Make the Right Decisions.



THANK YOU!

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