IMPACT BASED ALERTING SYSTEM USING AI-BASED RADAR MAPS FROM SATELLITE OBSERVATIONS

AOMSUC-13

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SI ANALYTICS

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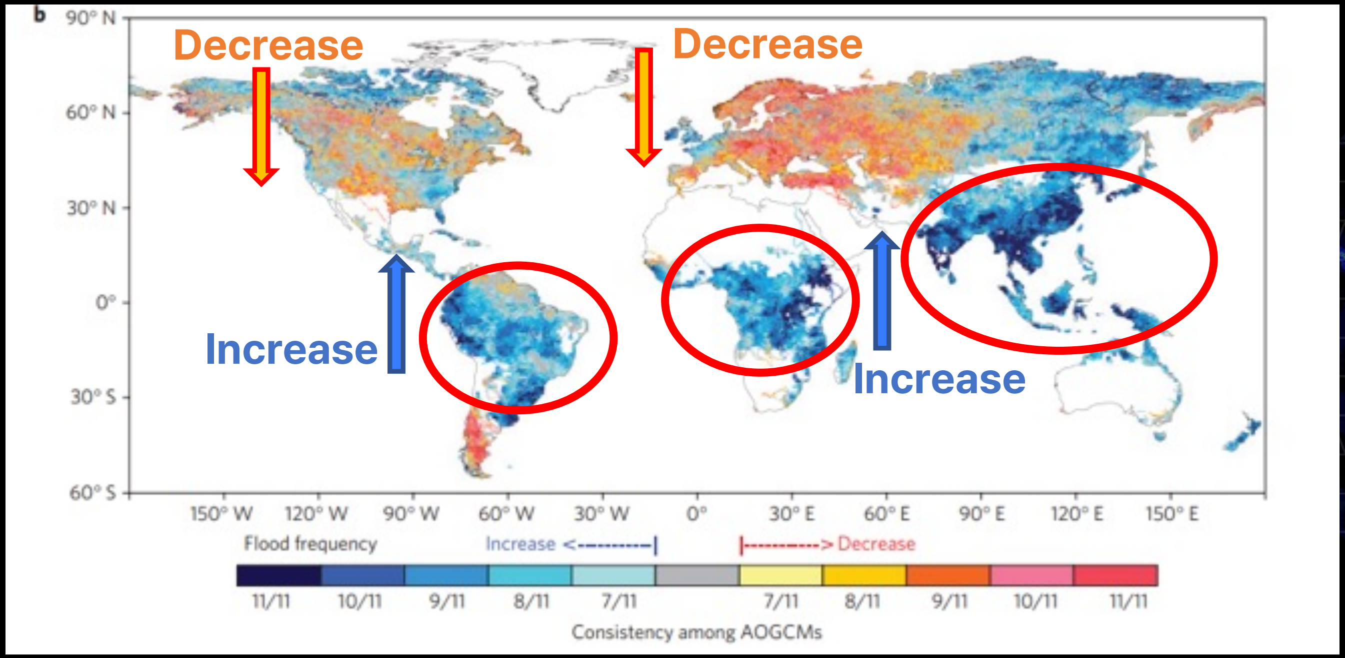
Chapter 01

Background

Background

- Weather radar detects and quantifies precipitation and severe weather conditions
- Radar system covers densely populated areas, but still insufficient to cover some regions and oceans



Flood frequency change [1]

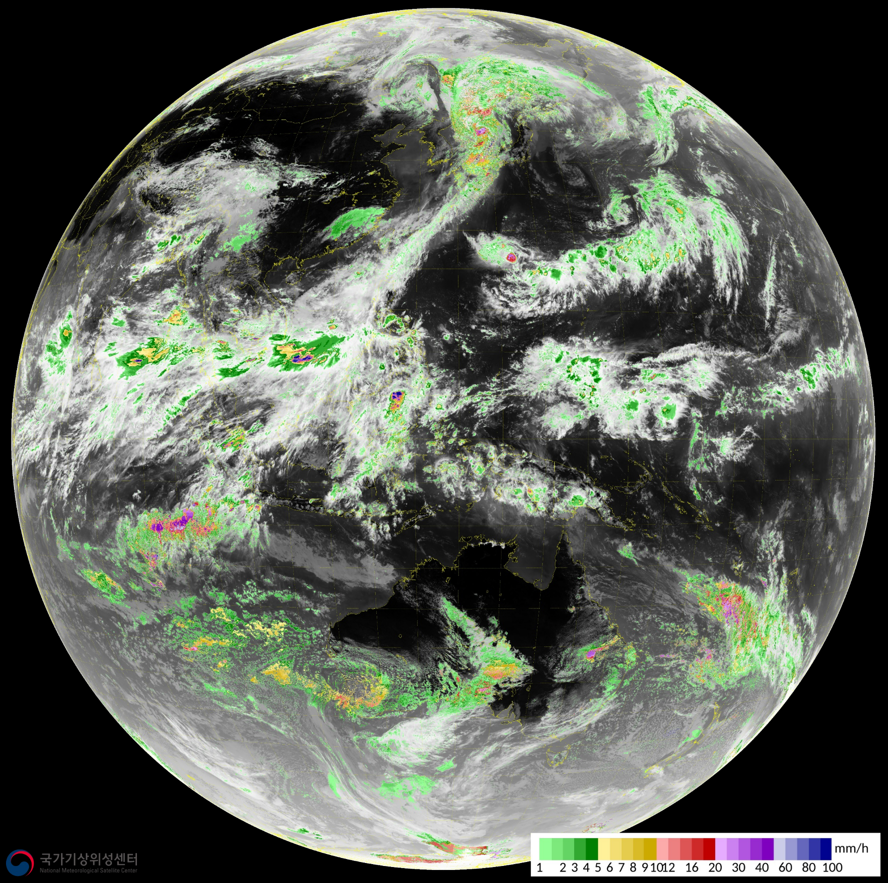
A map of weather radar coverage [2]

[1] Hirabayashi, Yukiko, et al. "Global flood risk under climate change." Nature climate change 3.9 (2013): 816-821..
[2] Saltikoff, Elena, et al. "An overview of using weather radar for climatological studies: successes, challenges, and potential." *Bulletin of the American Meteorological Society* 100.9 (2019): 1739-1752.

Background

Why Satellite?

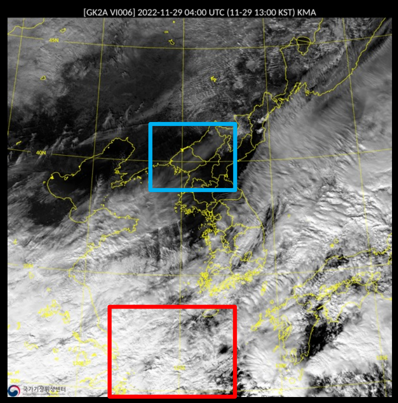
- Continuous and Wide observation area, High-resolution imagery, Spectral diversity



GEO-KOMPSAT-2A

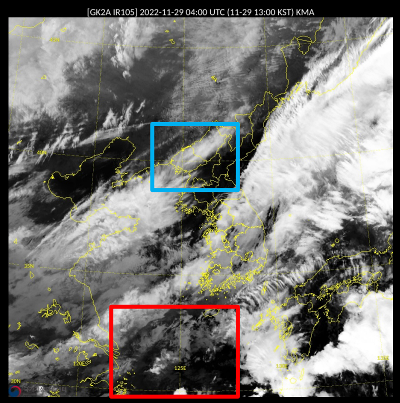
	Day time				All time											
GK2A	VIS0.4	VIS0.5	VIS0.6	VIS0.8	NIR1.3	NIR1.6	SWIR3.8	WV6.3	WV6.9	WV7.3	IR8.7	IR9.6	IR10.5	IR11.2	IR12.3	IR13.3

Visible (VIS)



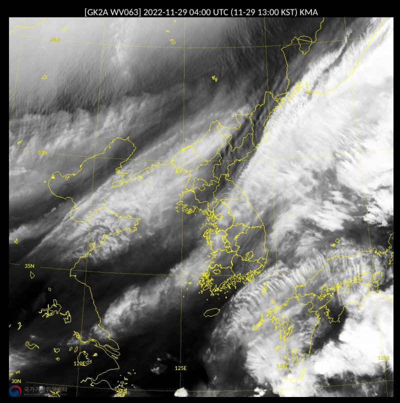
Low level clouds (Red box)

Infrared (IR)



High level cloud (Blue box)

Water vapor (WV)



Mid level water vapor

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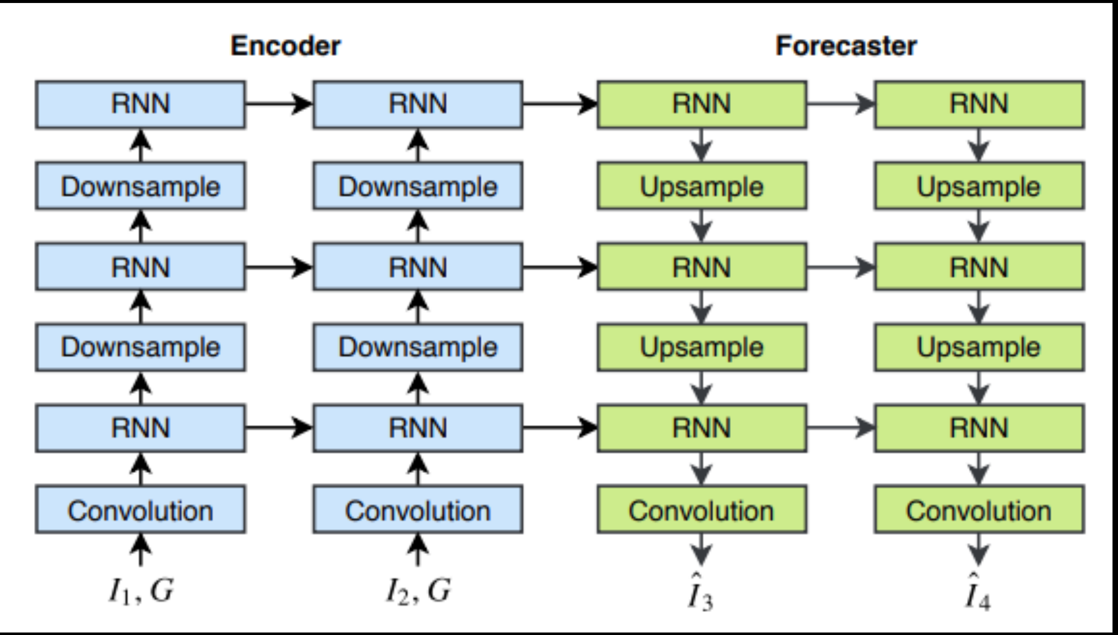
Background

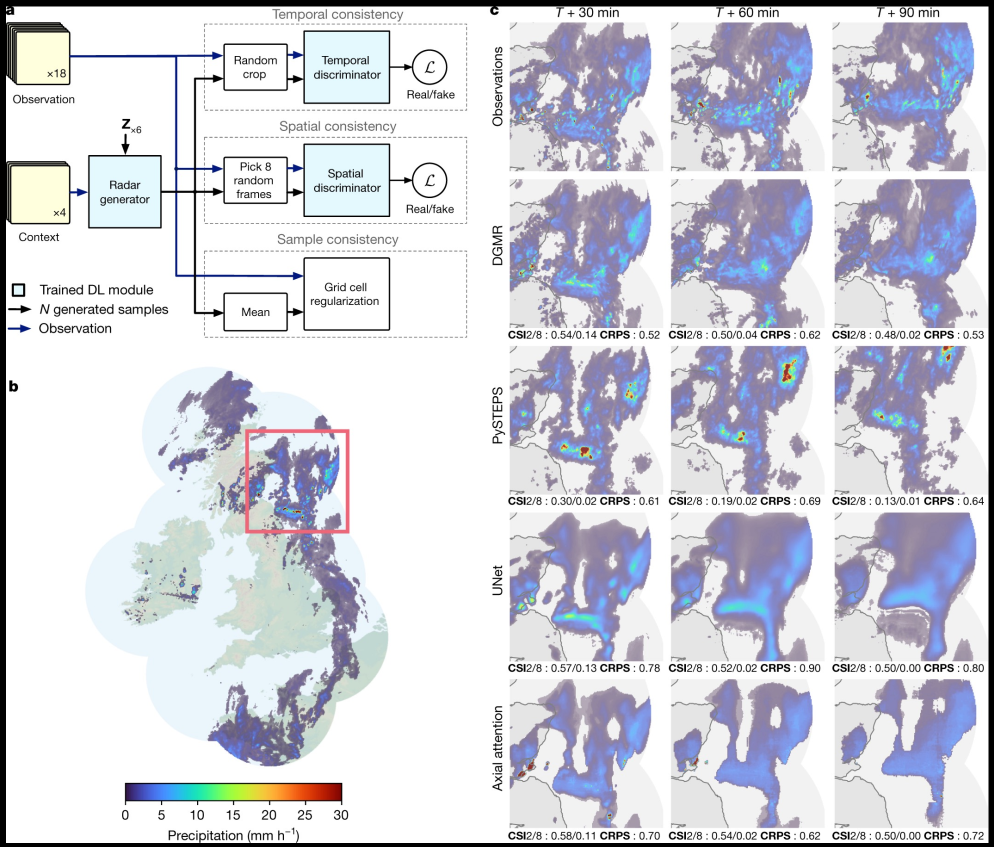
Deep learning-based weather forecasting model

- Video Frame Prediction



Trajectory GRU, [3]

- Deep generative model of Rain



DGMR, [4]

[3] Shi, Xingjian, et al. "Deep learning for precipitation nowcasting: A benchmark and a new model." *Advances in neural information processing systems* 30 (2017).
[4] Ravuri, Suman, et al. "Skilful precipitation nowcasting using deep generative models of radar." *Nature* 597.7878 (2021): 672-677.

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Goal

Accuracy Weather Forecasting without Radar System

Spatio-temporal limited detection → Geostationary satellite observation

Insufficient Radar system → Proxy radar map from satellite images

Chapter 02

Data and Method

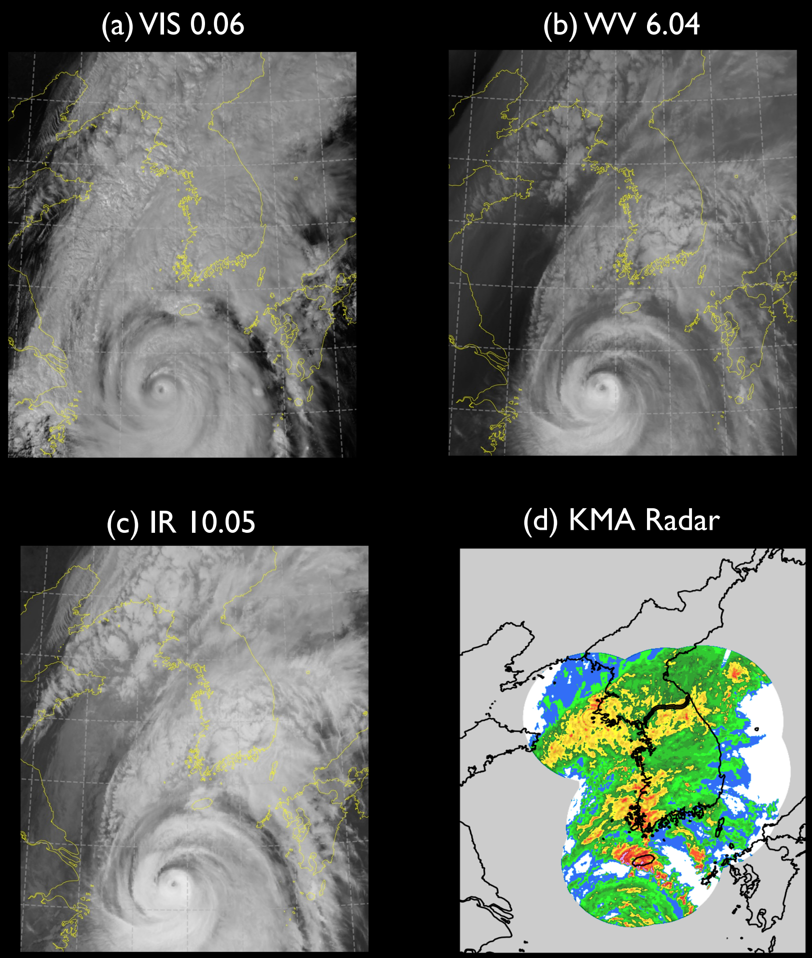
Data

Geo-KOMPSAT-2A (GK2A)

- Korean geostationary satellite
- 2-minutes interval and 0.5 to 2 km spatial resolution
- 16 channels – Including Visible (VIS), Water vapor (WV) and Infrared (IR) channels

KMA Weather Radar

- 5-minutes interval and 0.5 km spatial resolution



Test Cases:

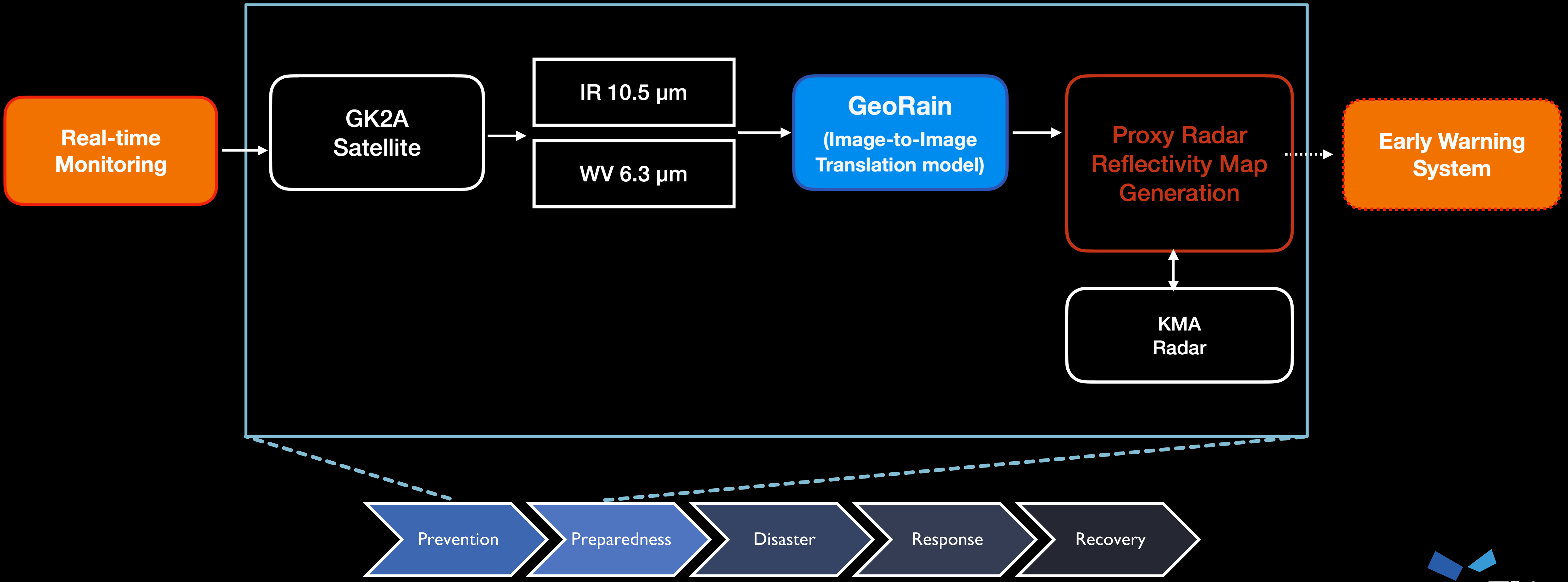
- 2023/01/12 2030 UTC (Heavy Rain)
- 2023/05/05 0730 UTC (Heavy Rain)
- 2023/07/14 0010 UTC (Jangma)
- 2022/08/09 1020 UTC (Typhoon Hinnamnor)

*KMA: Korean Meteorological Administration

SIA's Disaster Monitoring Model

Part of the real-time disaster monitoring model

- A proxy radar map is generated to detect and predict heavy rain events

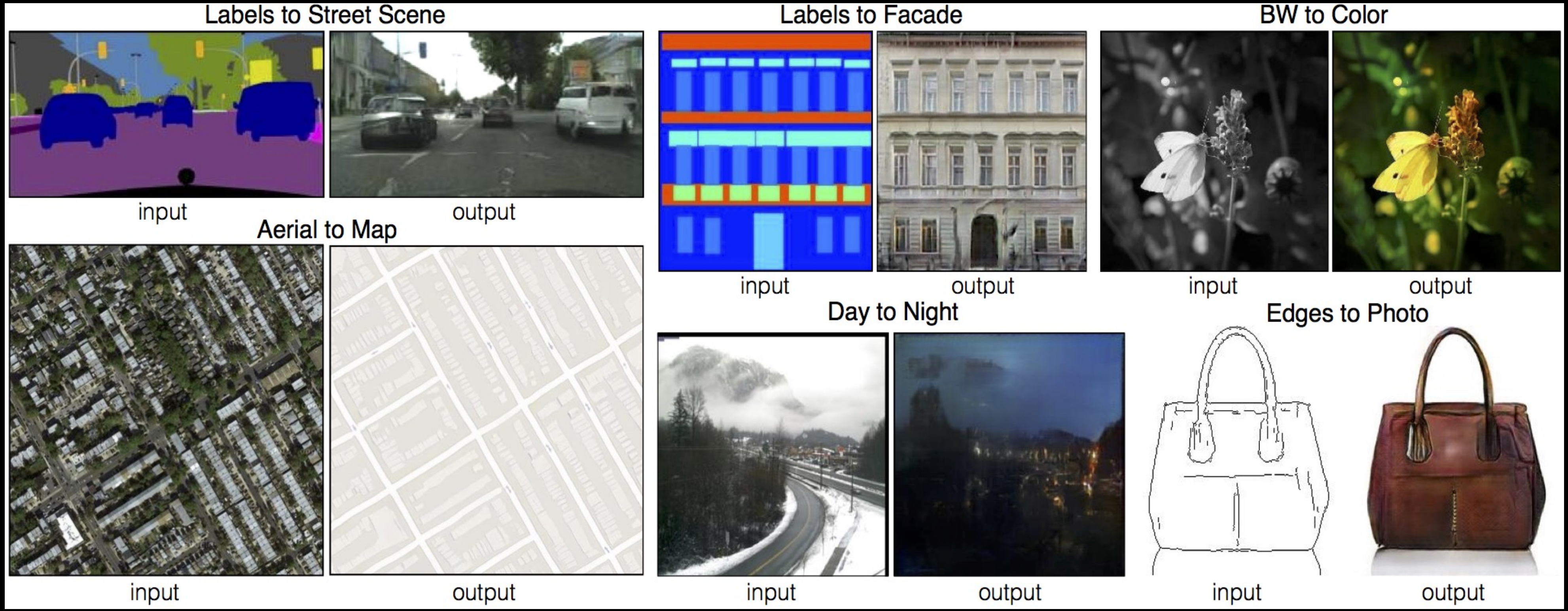


Overview of disaster management process

GeoRain_v1.0

Generative Adversarial Network for rain – GeoRain

- Isola et al.(2017)[5] suggested a general-purpose solution to resolve image-to-image translation problems using conditional GANs (cGAN)

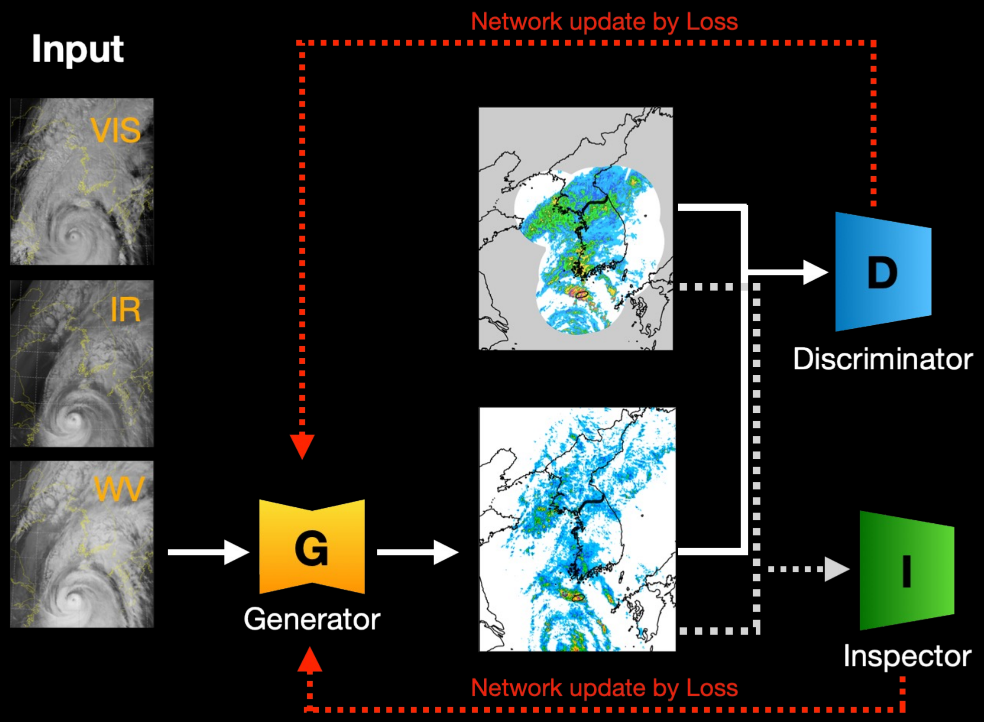


[5] Isola, Phillip, et al. "Image-to-image translation with conditional adversarial networks. arXiv e-prints." arXiv preprint arXiv:1611.07004 (2016).

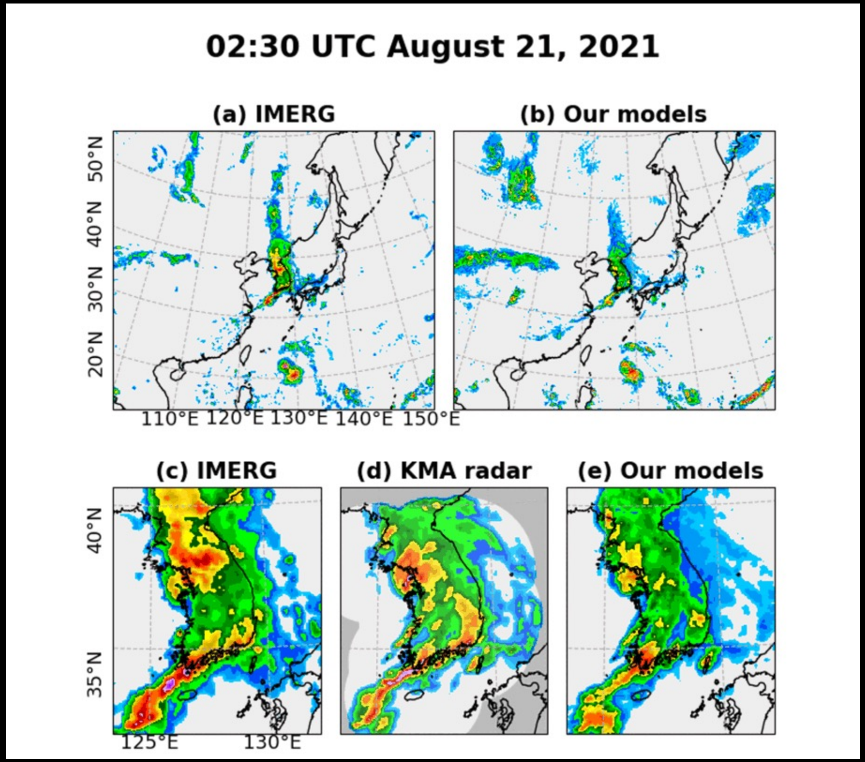
GeoRain_v1.0

Generative Adversarial Network for rain – GeoRain

- Generate proxy radar reflectivity map using Pix2PixCC model ([6])
- Inspector guides the generated image to be physically consistent with the real image



Overview of GeorAIn [6]



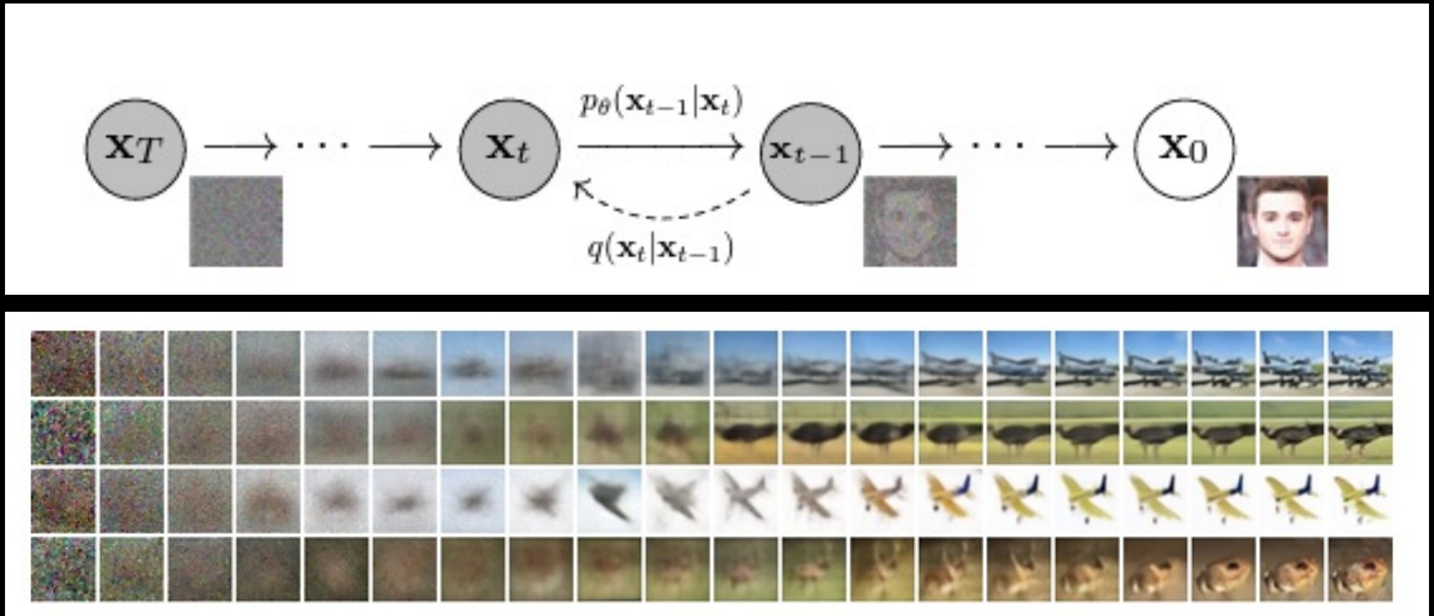
Qualitative results of GeorAIn [7]

[6] Yim et al. "Global Radar Precipitation Map Generation from Integrated Geostationary Satellite Products Using Deep Learning Approaches." (AMS, 2023).
[7] Jeong, Hyun-Jin, et al. "Improved AI-generated Solar Farside Magnetograms by STEREO and SDO Data Sets and Their Release." *The Astrophysical Journal Supplement Series* 262.2 (2022): 50.

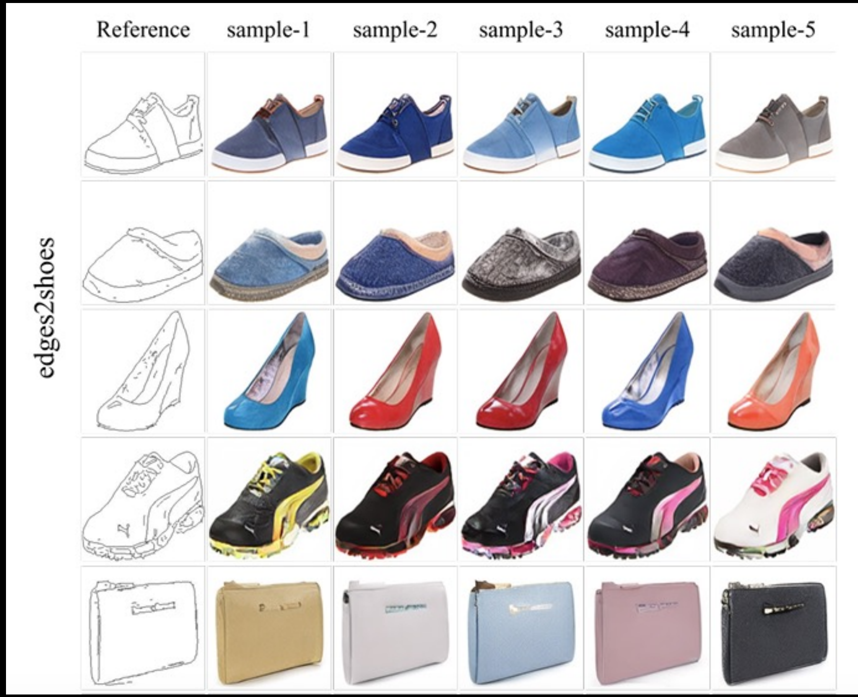
GeoRain_v2.0

Diffusion-based rain forecasting model

- Generate proxy radar reflectivity map using diffusion model (BBDM, [8])
- High Sample diversity and model stability than GAN –based model



Diffusion model structure and results [9]



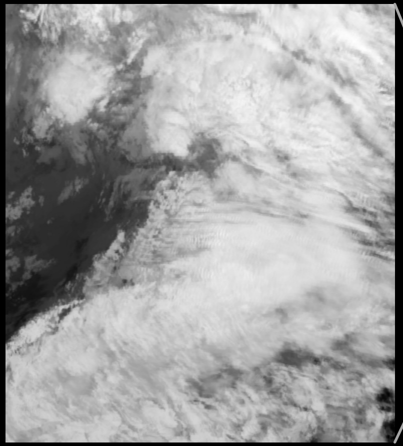
Diverse samples from BBDM [9]

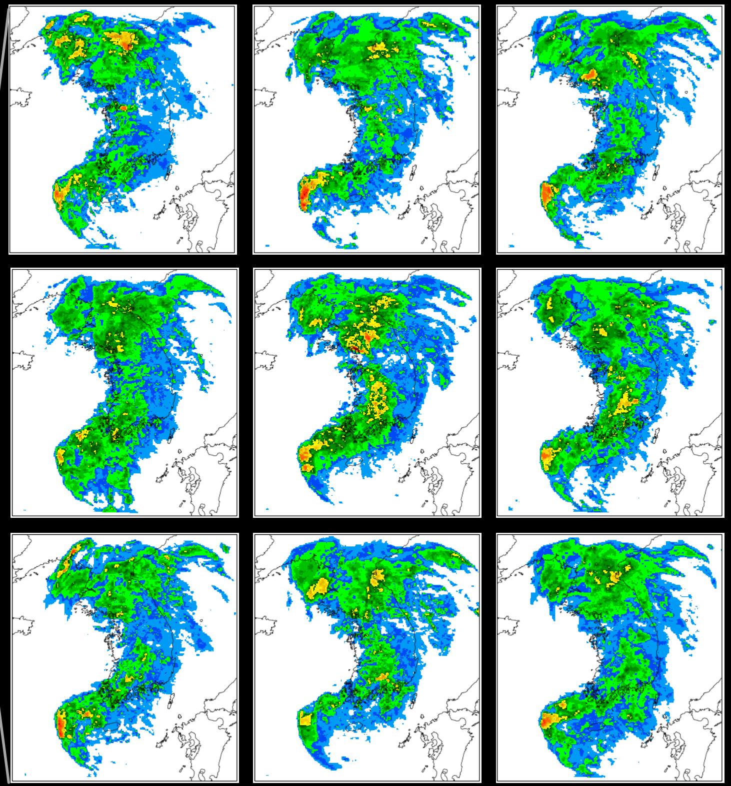
[8] Li, Bo, et al. "BBDM: Image-to-image translation with Brownian bridge diffusion models." Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition. 2023.
[9] Ho, Jonathan, Ajay Jain, and Pieter Abbeel. "Denoising diffusion probabilistic models." Advances in neural information processing systems 33 (2020): 6840-6851.

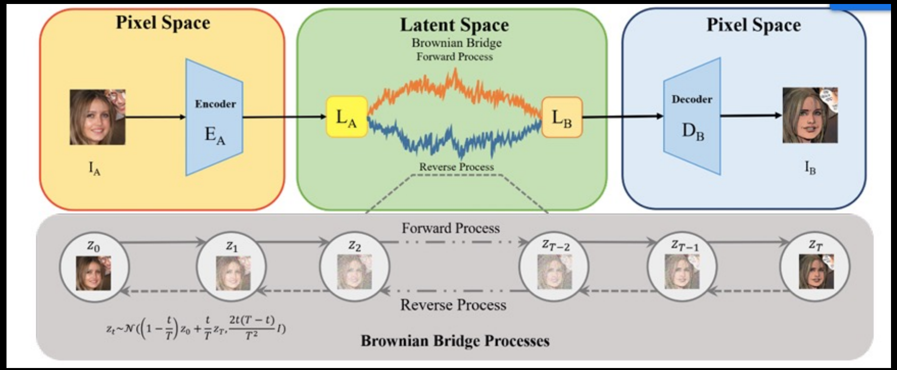
GeoRain_v2.0

Diffusion-based rain forecasting model

- Generate proxy radar reflectivity map using diffusion model (BBDM, [8])







Architecture of BBDM [8]

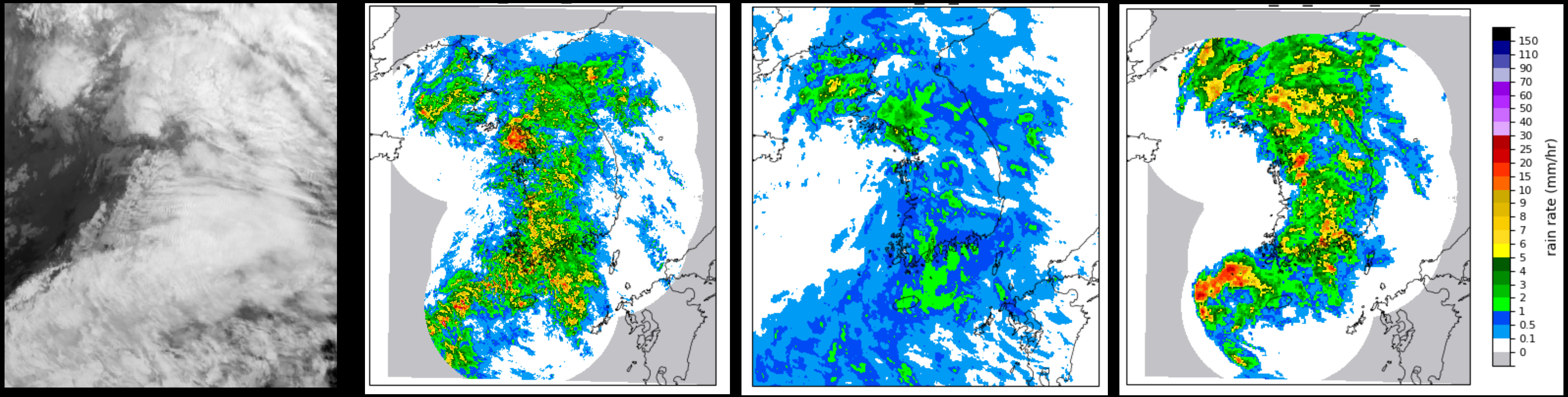
[8] Li, Bo, et al. "BBDM: Image-to-image translation with Brownian bridge diffusion models." Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition. 2023.

Chapter 03

Results

Results: Case-1

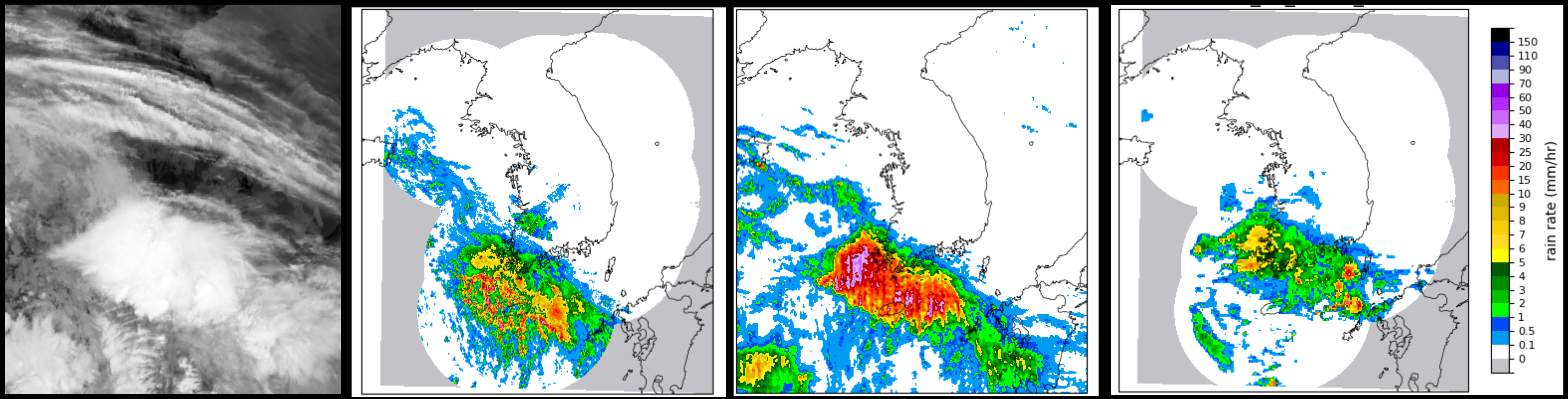
1) 2023/01/12 2030 UTC – Moderate Rain



(a) GK2A IR 10.5 (b) KMA_radar (c) GeoRain_v1.0 (d) GeoRain_v2.0

Results: Case-2

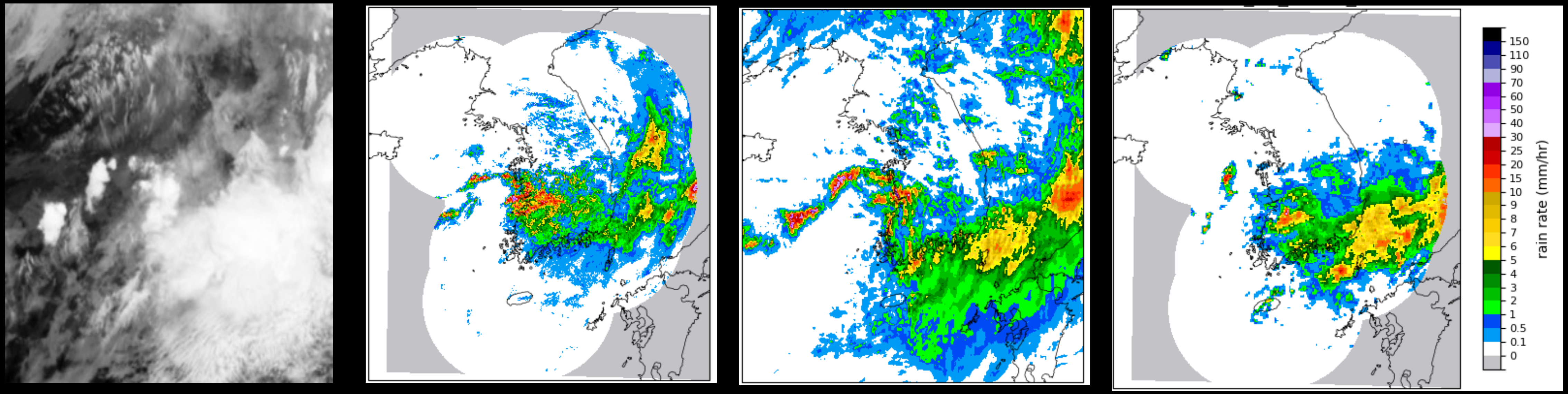
2) 2023/05/04 0100 UTC – Heavy Rain



(a) GK2A IR 10.5 (b) KMA_radar (c) GeoRain_v1.0 (d) GeoRain_v2.0

Results: Case-3

3) 2023/07/14 0010 UTC – Heavy Rain(Jangma)



(a) GK2A IR 10.5

(b) KMA_radar

(c) GeoRain_v1.0

(d) GeoRain_v2.0

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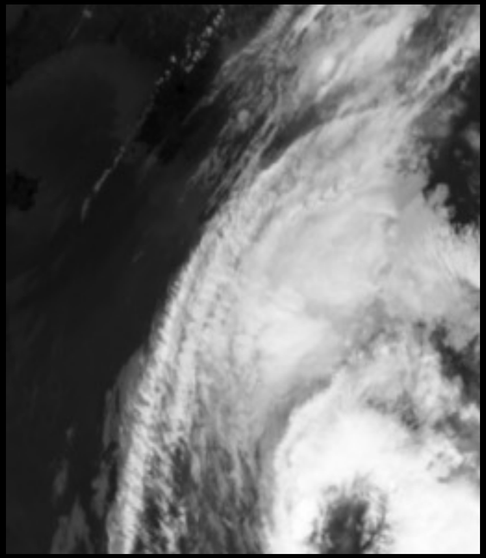
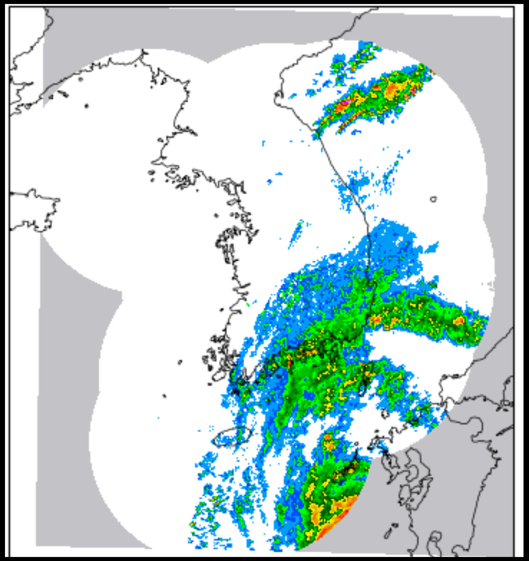
Results: Case-4

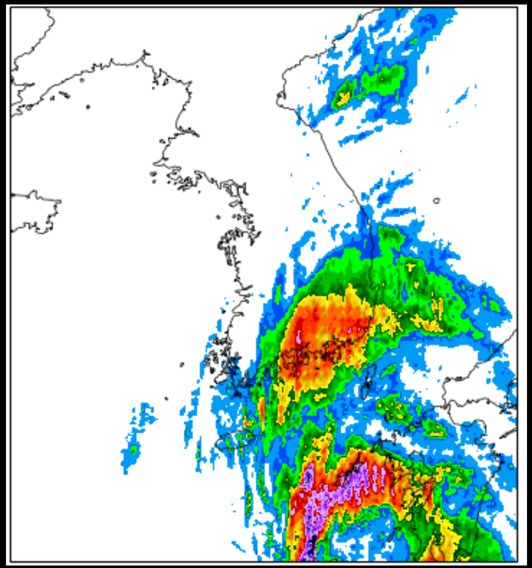
4) 2023/08/09 0120 UTC – Typhoon Hinnamnor



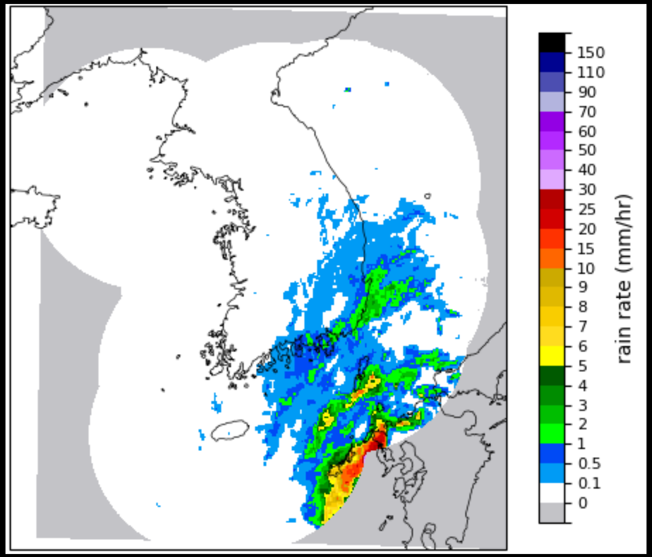
(a) GK2A IR 10.5



(b) KMA_radar



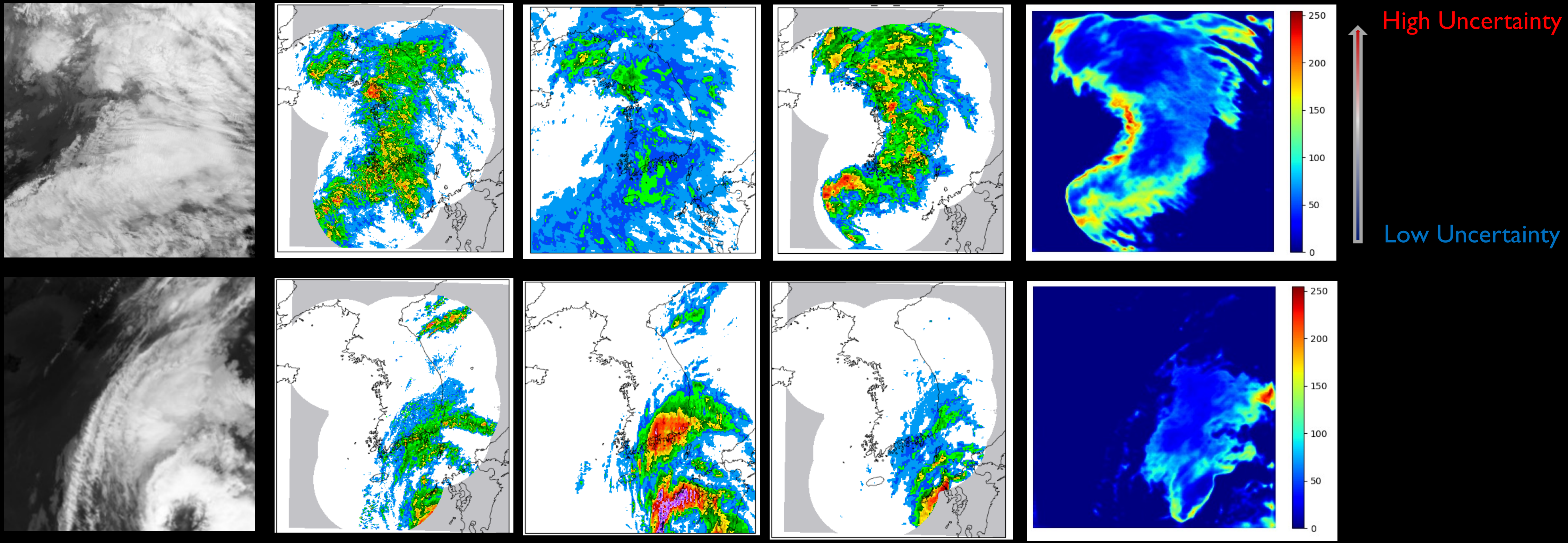
(c) GeoRain_v1.0



(d) GeoRain_v2.0

Results: Stochastic results

Diffusion model can generate stochastic forecasting



(a) GK2A IR 10.5

(b) KMA_radar

(c) GeoRain_v1.0 (Deterministic result)

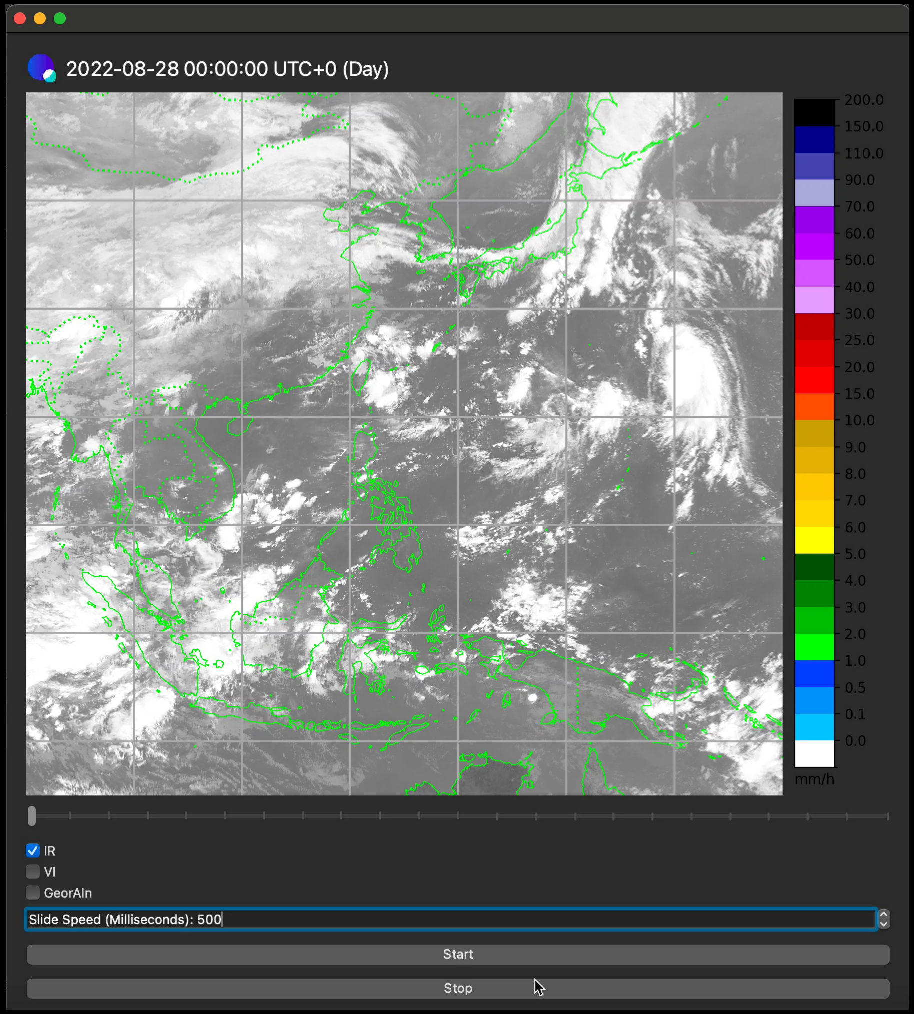
(d) GeoRain_v2.0

(e) GeoRain_v2.0 (Variance map)

Conclusions

- We generate proxy rainfall maps by using GeoRain model with geostationary satellite imageries .
- The GeoRain results show our model can predict the accurate timing, location, and intensity of heavy rain areas.
- The GeoRain_v1.0 shows overestimated results than the GeoRain_v2.0.
- Diffusion-based GeoRain_v2.0 model can generate stochastic results that take uncertainty into account.

- We expect our service to help communicate preemptive and precise early warnings.
- We plan to expand our disaster monitoring model to predict future precipitation on a global scale.



Thank you for attention

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Appendix

- Training information – GeoRain models

	WR-Net	GeoRain_v1	GeoRain_v2
Training data	GK2A 2020.08-2021.07, 2 min	GK2A 2019.08-2021.07. 10 min	
Base model	TV-L1 algorithm (optical flow)/ U-Net based VGG16 (refinement)	Pix2PixCC model	Diffusion model(BBDM)
Loss function	PSNR, SSIM	LSGAN, FM loss, CC loss	BBDM score loss
Optimizer	Adam	Adam	Adam
Learning Rate	1e-4	0.0002	1e-4