기상청 책임운영기관 국립기상과학원 National Institute of Meteorological Sciences

Towards an Operational Precipitation Nowcasting Model with Memory-Efficient Bidirectional Transformers

The Bureau of Meteorology R&D Workshop

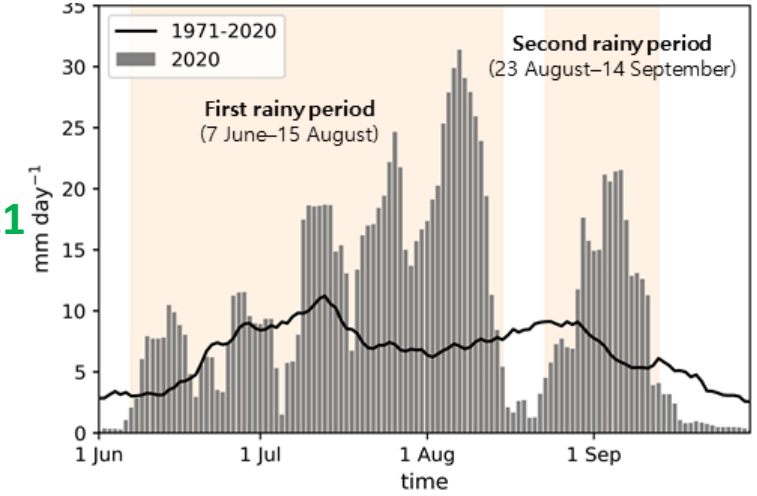
Hyesook Lee[1], Jieun Cha[1], Seong-Hun Pyo[1],
Kijun Park[1], Jaehoon Yoo[2], Seunghoon Hong[2]

1. National Institute of Meteorological Sciences, KMA
2. Korea Advanced Institute of Science and Technology

Heavy Rainfall Events in Summer

Station-Averaged Daily Rainfall in 2020

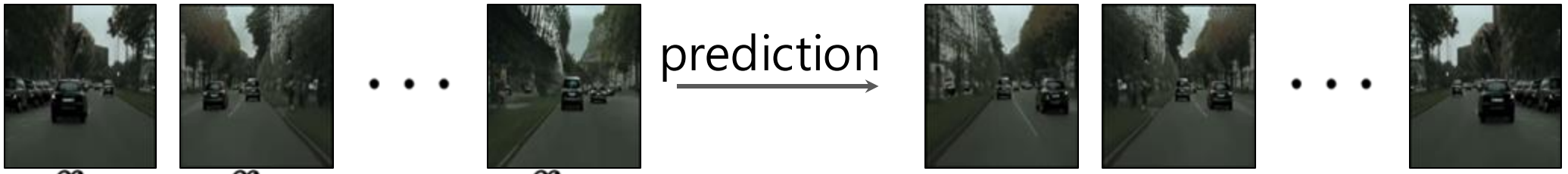
Park et al. 2021



Examples...

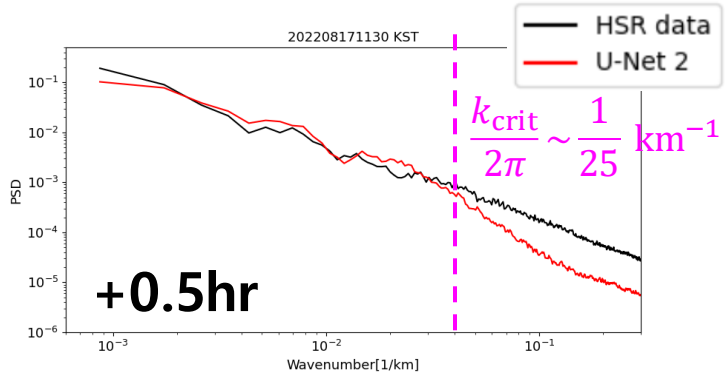
Precipitation Nowcasting using AI: Video Prediction Problem

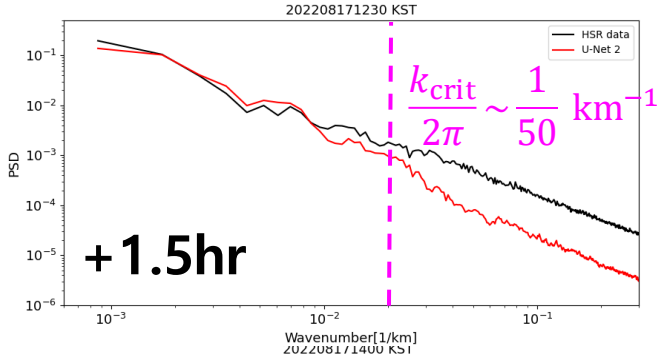
Context frames → prediction → **Future frames**

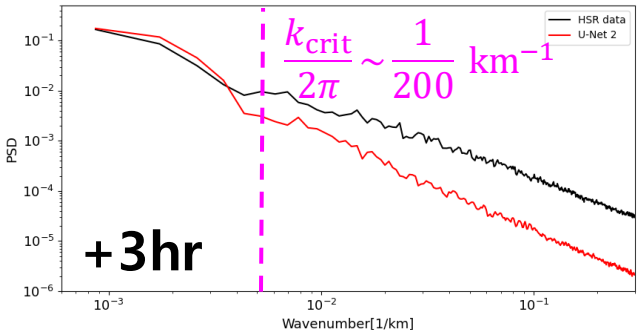


Convolutional Neural Network for Nowcasting

Power Spectral Density



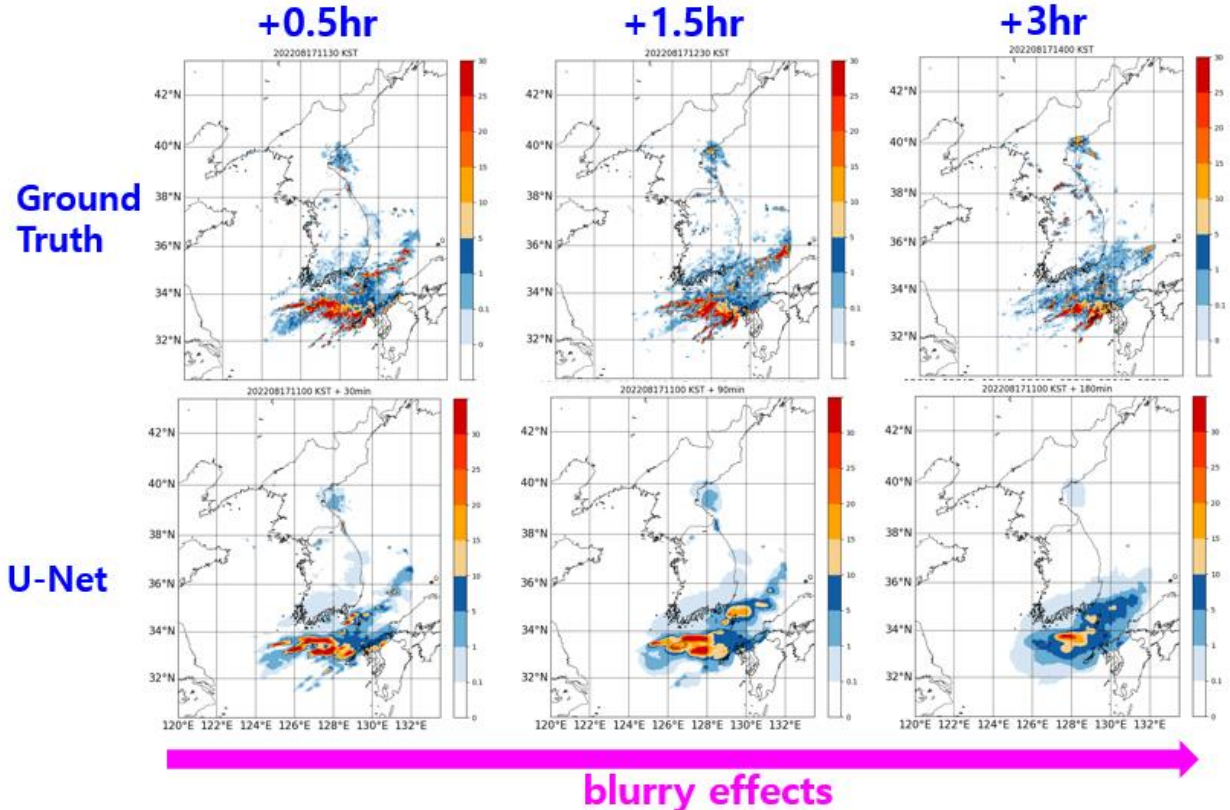




***Loss function based on CSI**

$$L_{CSI} = -\frac{1}{2}\left(\frac{TP_{\geq 1mm/h}}{TP_{\geq 1mm/h} + FP_{\geq 1mm/h} + FN_{\geq 1mm/h}} + \frac{TP_{\geq 10mm/h}}{TP_{\geq 10mm/h} + FP_{\geq 10mm/h} + FN_{\geq 10mm/h}}\right)$$

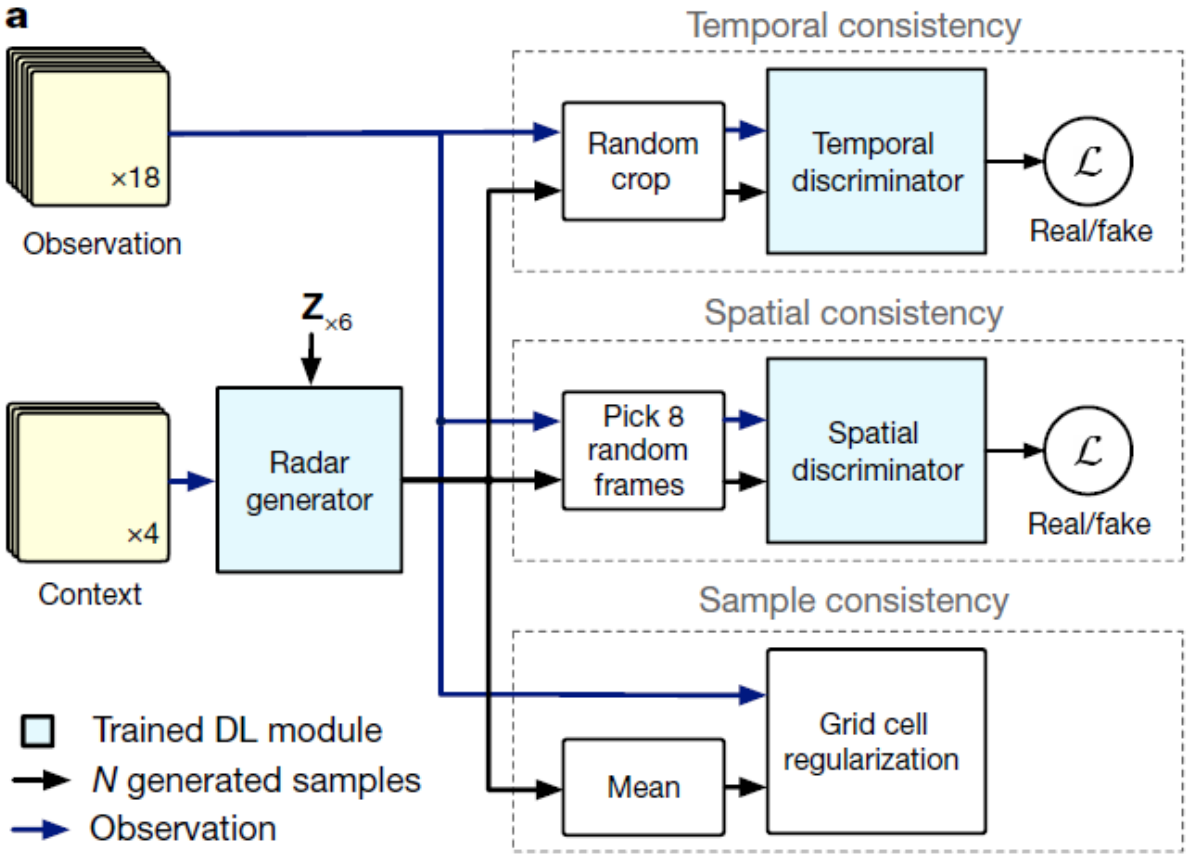
(Ko et al. 2022, Oh et al. 2023)

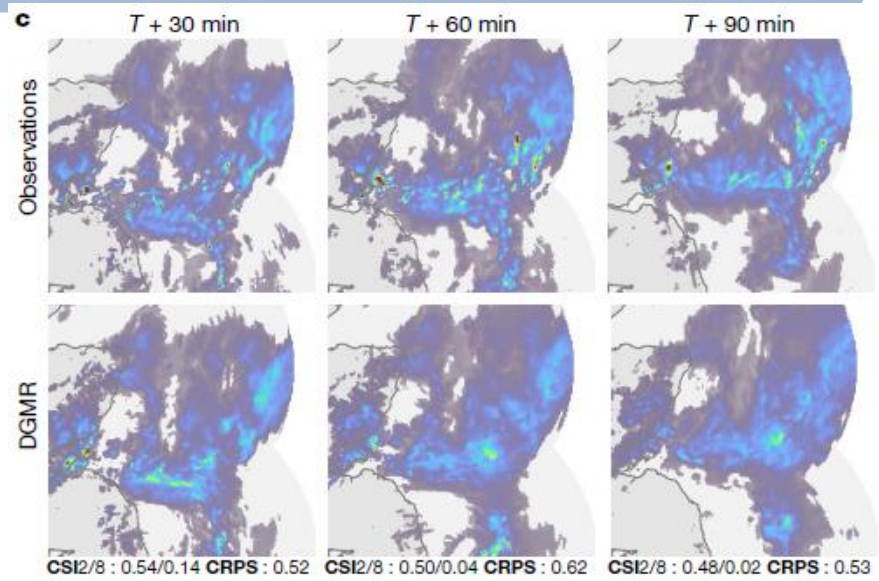


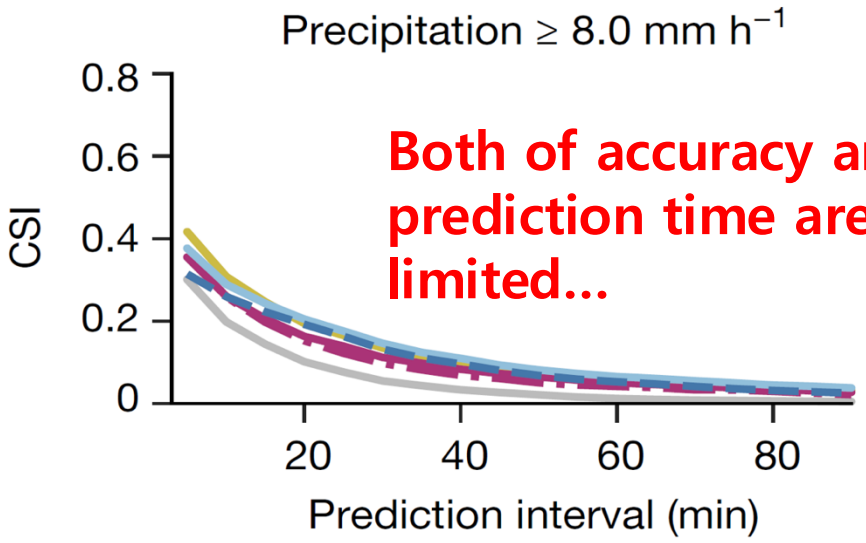
Precipitation Nowcasting Using GAN

Deep Generative Model of Radar (DGMR)

(Ravuri et al. 2021)



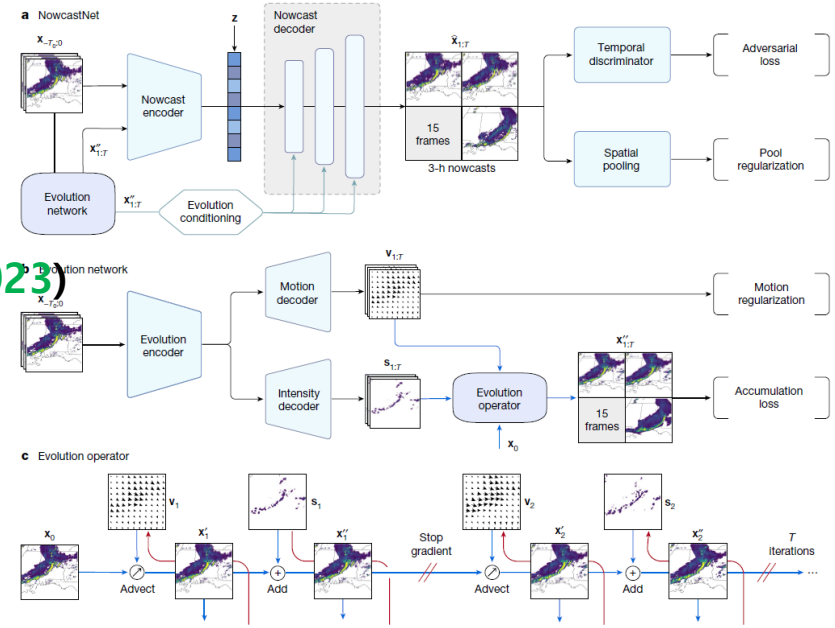




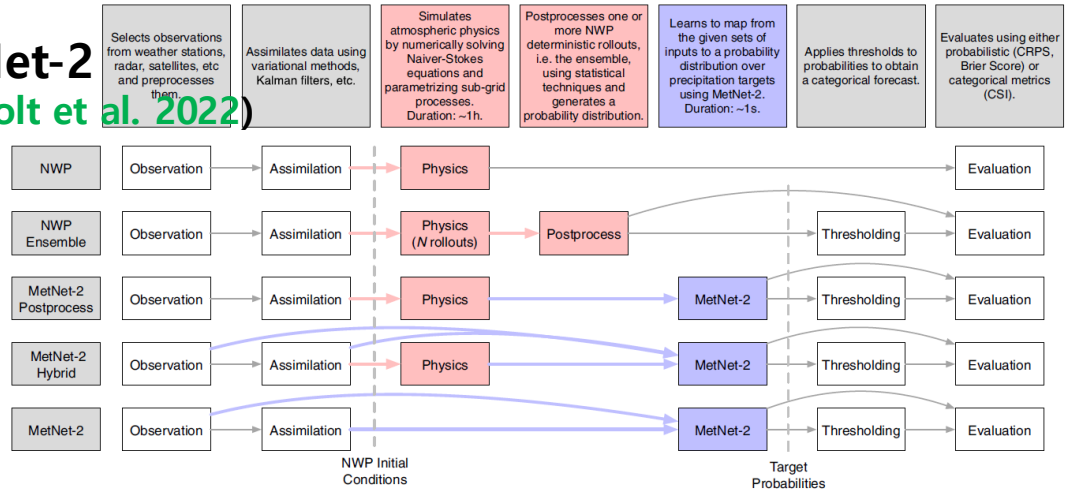
Both of accuracy and prediction time are very limited…

Recent Progress on Improving Nowcasting Performance

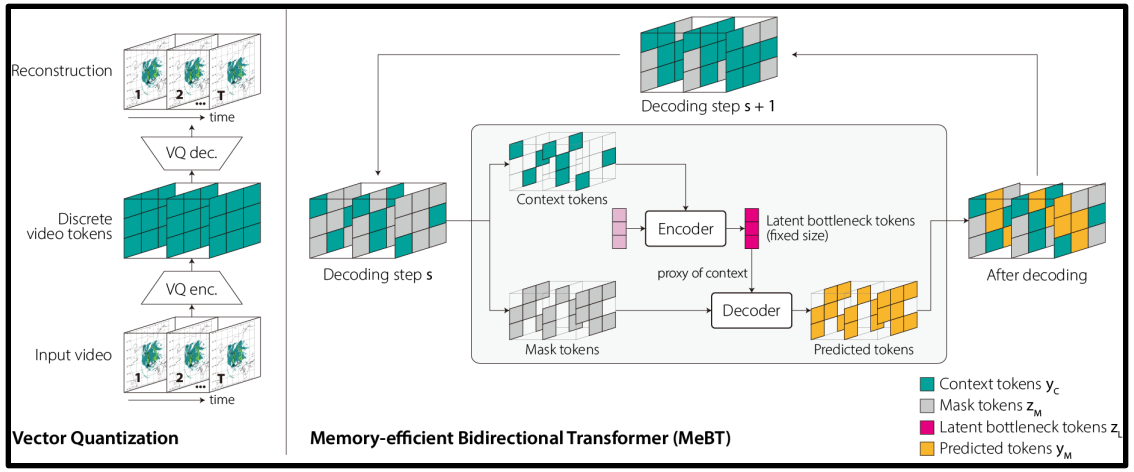
NowcastNet (Zhang et al. 2023)



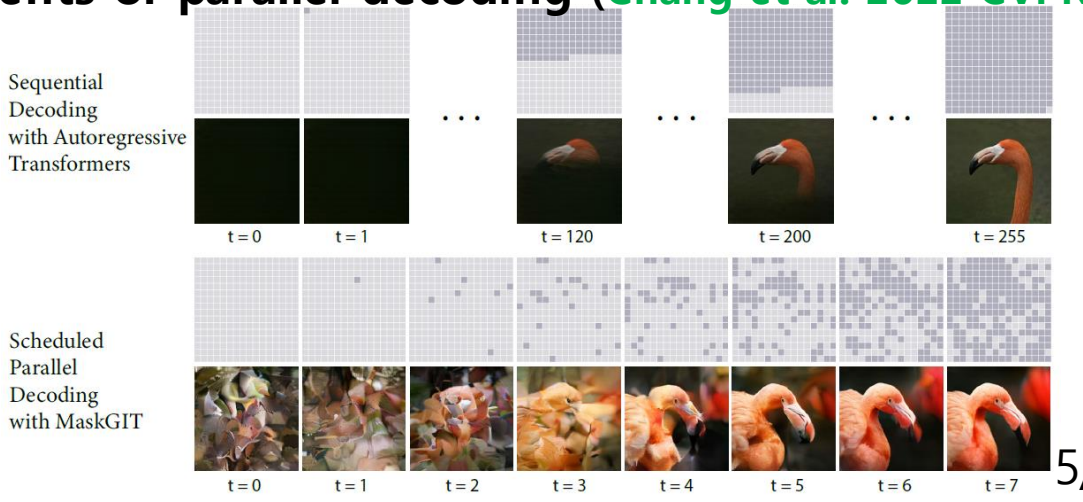
MetNet-2 (Espeholt et al. 2022)



NIMS/KMA: Long Video Generation Using Transformer (Yoo et al. 2023; Yoo et al. in Prep.)

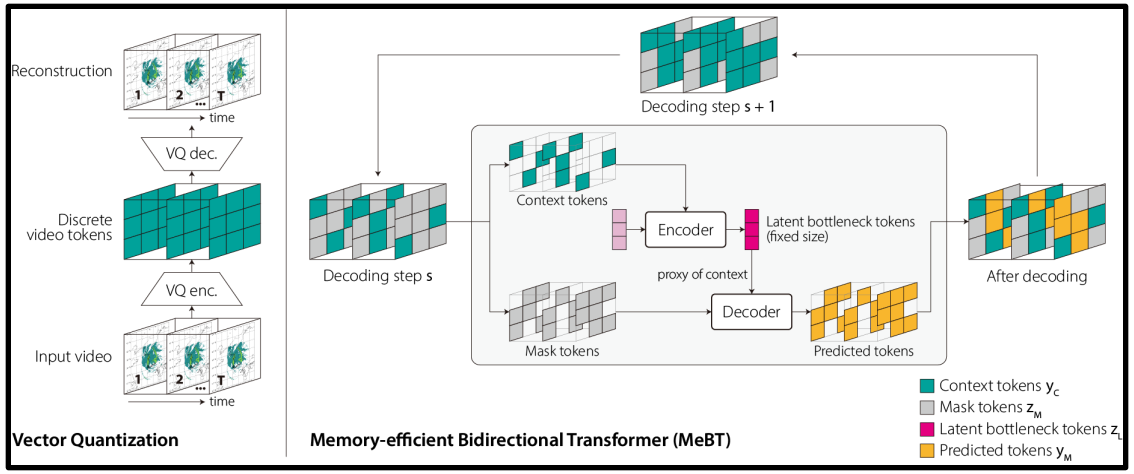


Benefits of parallel decoding (Chang et al. 2022 CVPR)

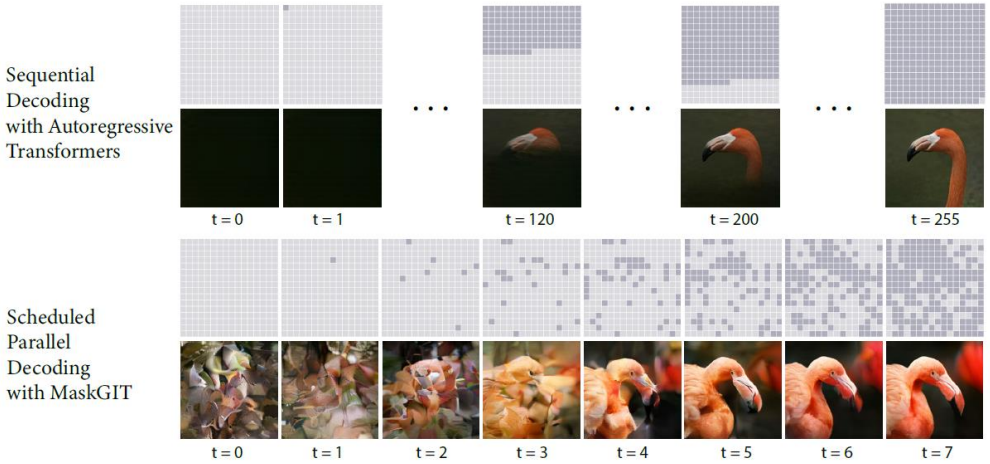


NIMS/KMA: Video Generating Transformer for Nowcasting

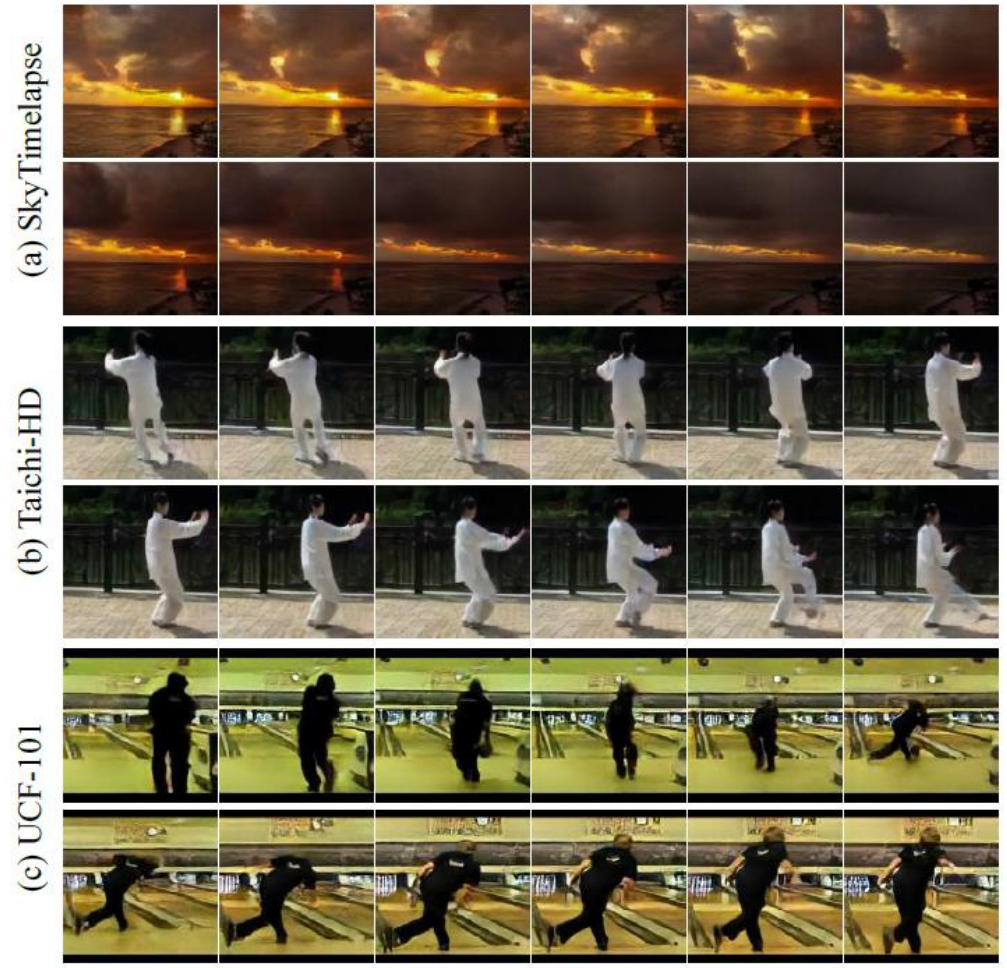
NIMS/KMA: Long Video Generation Using Transformer (Yoo et al. 2023; Yoo et al. in Prep.)



Benefits of parallel decoding (Chang et al. 2022 CVPR)



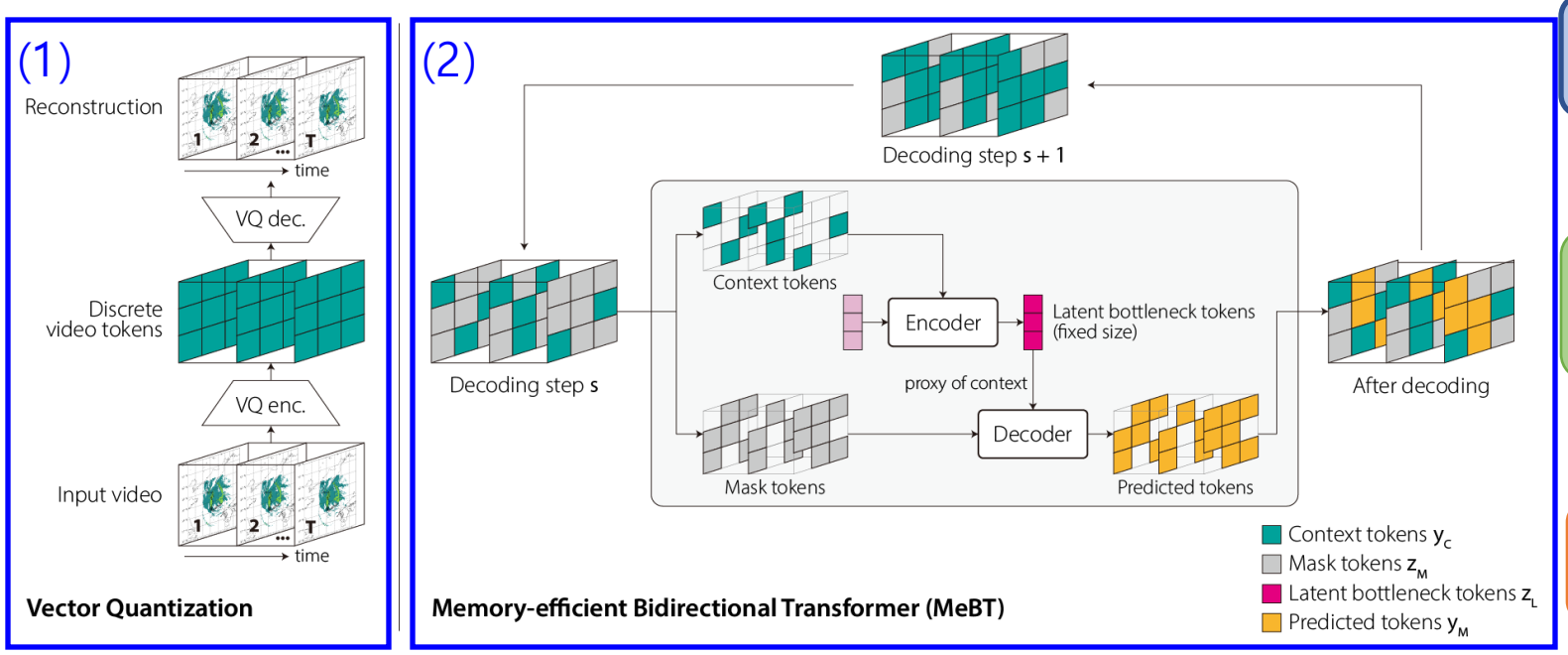
Examples of qualitative results (Yoo et al. 2023)



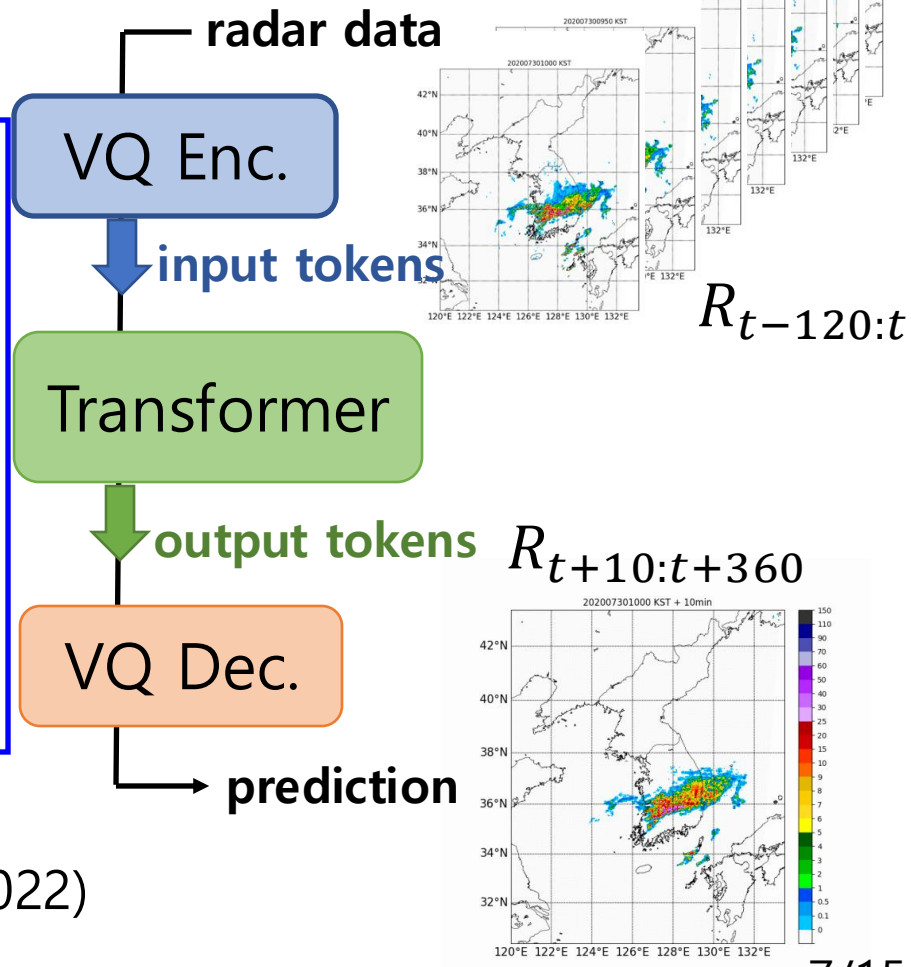
기상청 국립기상과학원 National Institute of Meteorological Sciences
책임운영기관

Transformer Model for Precipitation Nowcasting

- (1) Feature extractions using GAN structure
- (2) Future prediction using transformer



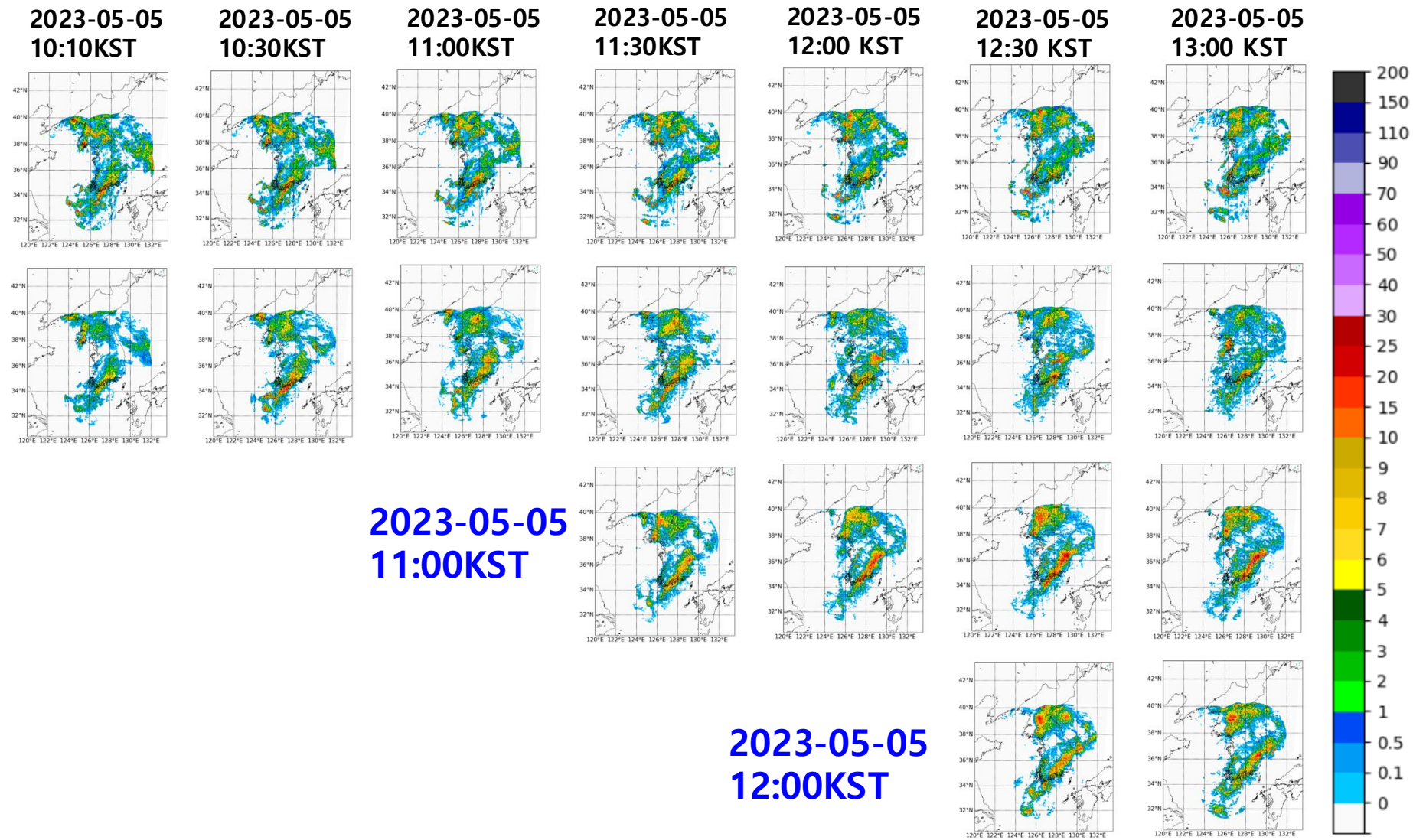
(Yoo et al. 2023 CVPR)



❖ Radar dataset:

- Training: 7-year data (2014, 2016, 2017, 2018, 2019, 2021, 2022)
- Validation & test: 3-year data (2015, 2020, 2023)

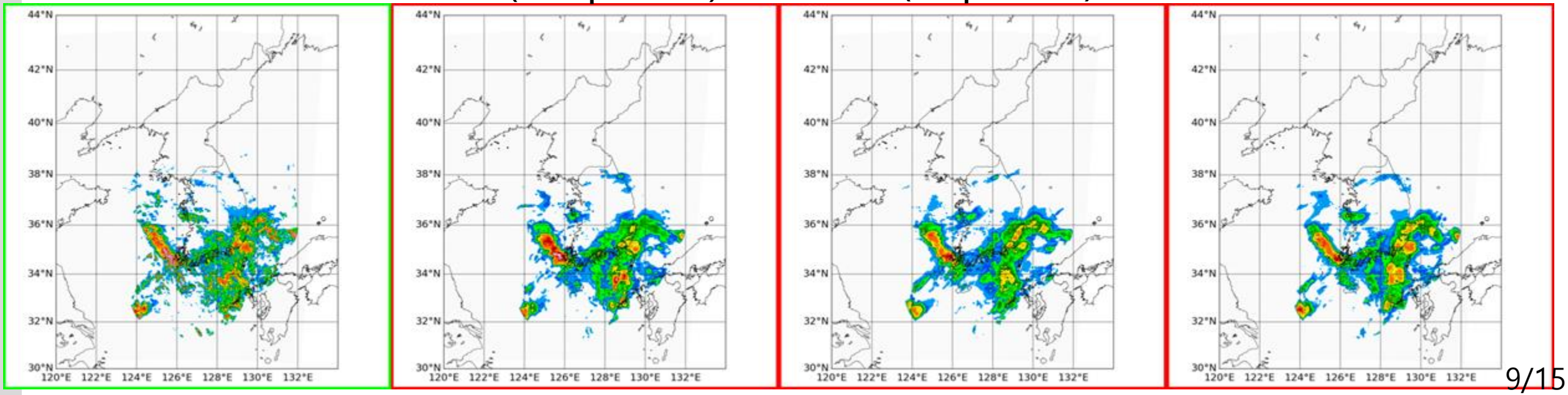
Example of Nowcasting Output(2023-05-05 10 KST)



	As is (`22~`23)	To be (`24)
Source Data	Radar Reflectivity, AWS	Radar Reflectivity, AWS
Spatial/Temporal Resolution	1 km / 10 min	1 km / 10 min
Method	2D VQGAN + Transformer (only Spatial Feature considered)	3D VQGAN + Transformer (Spatial/Temporal Feature considered)
Training data	2014, 2016~2019, 2021~2022	2014~2019, 2021~2023
Evaluation/Test	2015, 2020, 2023	2020, 2024
Input Data	Past 1 hour's data	Past 2 hours' data
Output Data	Precipitation forecast (up to 3hrs, 10min interval)	Precipitation forecast (up to 6hrs, 10min interval)

2020.05.03. 02:00 KST

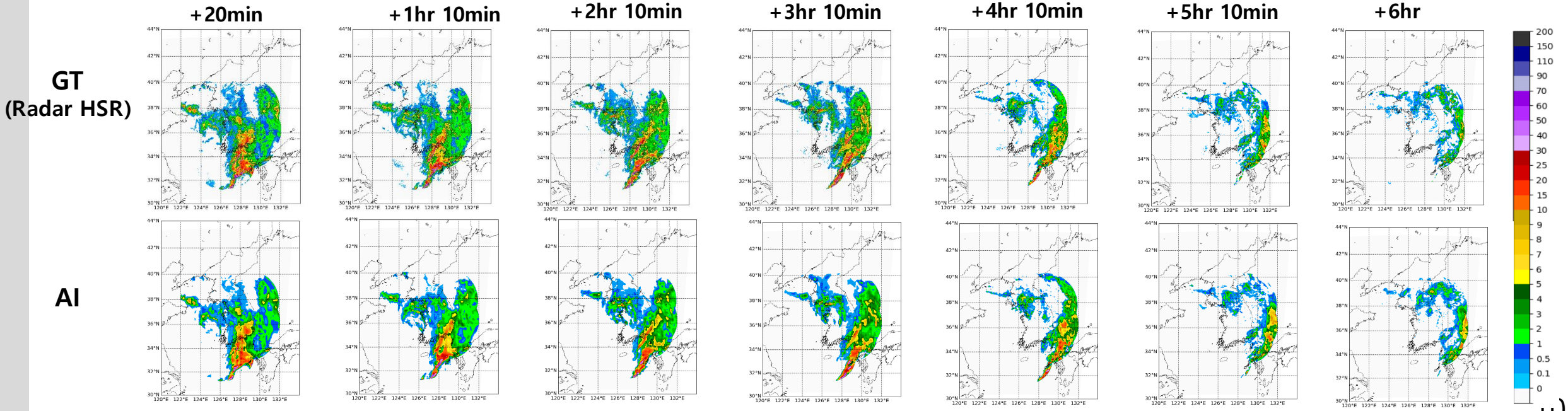
GT (Radar HSR) | **'24 (more parameter)** | **'24 (less parameter)** | **'22~'23**



기상청 책임운영기관 국립기상과학원 National Institute of Meteorological Sciences

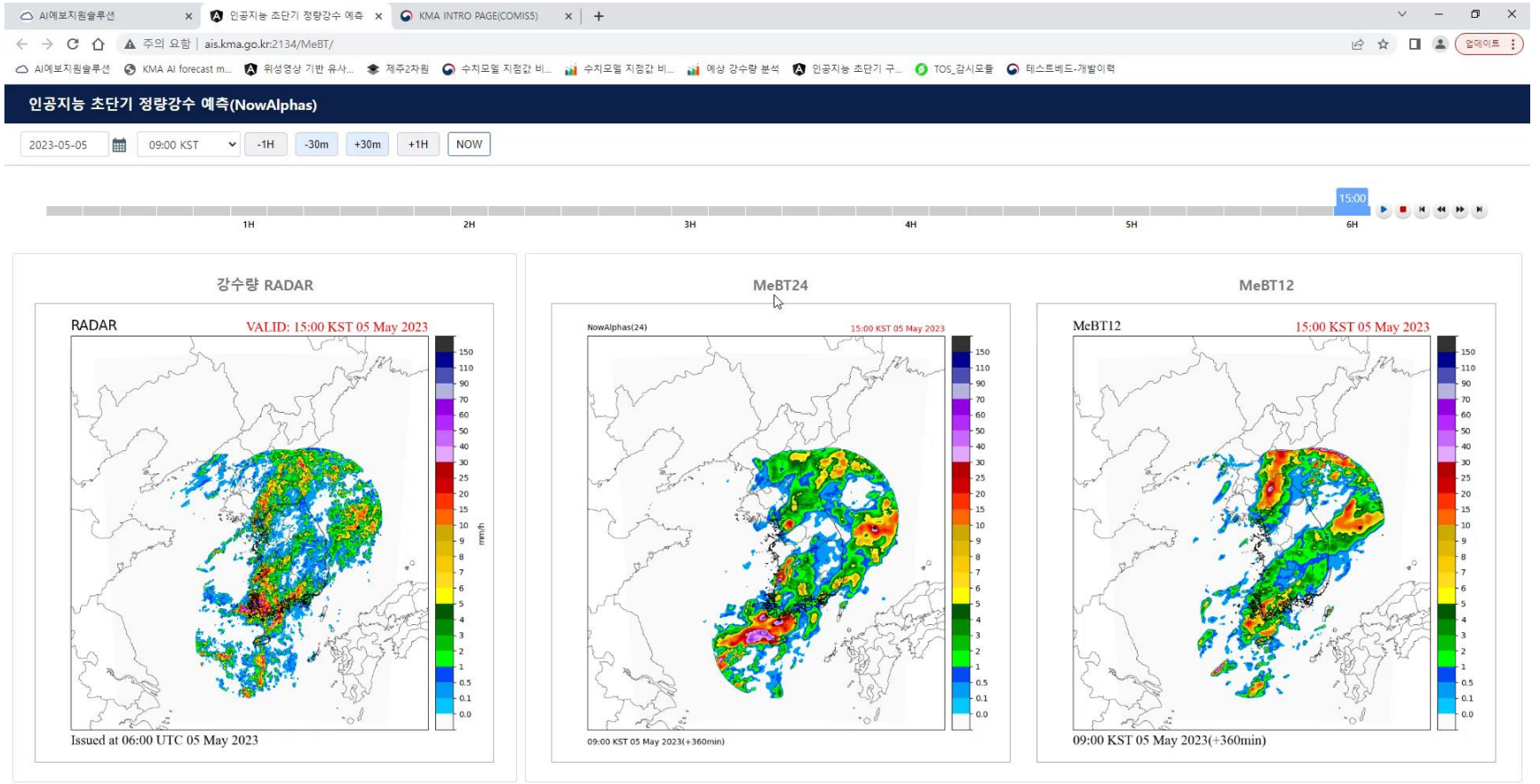
	As is (`22~`23)	To be (`24)
Source Data	Radar Reflectivity, AWS	Radar Reflectivity, AWS
Spatial/Temporal Resolution	1 km / 10 min	1 km / 10 min
Method	2D VQGAN + Transformer (only Spatial Feature considered)	3D VQGAN + Transformer (Spatial/Temporal Feature considered)
Training data	2014, 2016~2019, 2021~2022	2014~2019, 2021~2023
Evaluation/Test	2015, 2020, 2023	2020, 2024
Input Data	Past 1 hour's data	Past 2 hours' data
Output Data	Precipitation forecast (up to 3hrs, 10min interval)	Precipitation forecast (up to 6hrs, 10min interval)

2024.05.06. 00:00 KST (model under training)



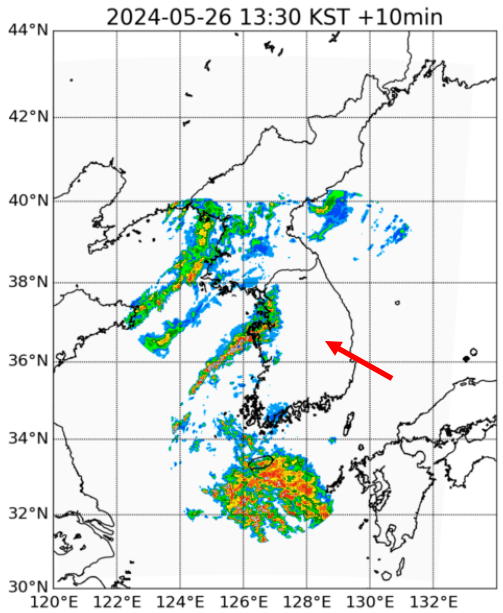
Real-time Evaluation of Model Results

- **(Period)** July 1, 2024 at 00:00 UTC ~
- **(Evaluation area)** Korean Peninsula (1,152×1,440 pixels, spatial resolution: 1km)
- **(Nowcasting outputs)** 10-min interval, 0-6h lead times, 30min update cycle

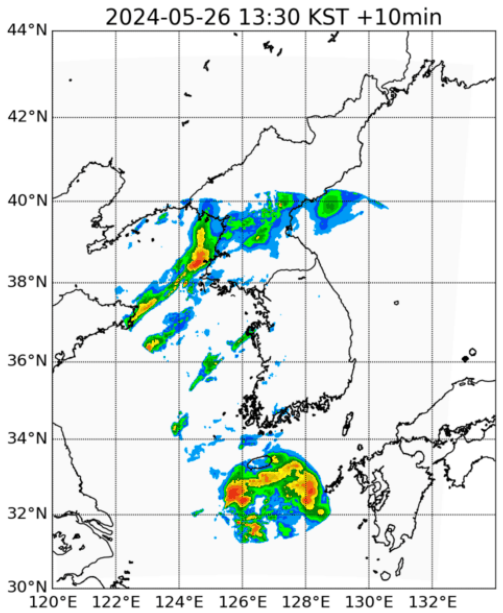


Future work – curriculum learning

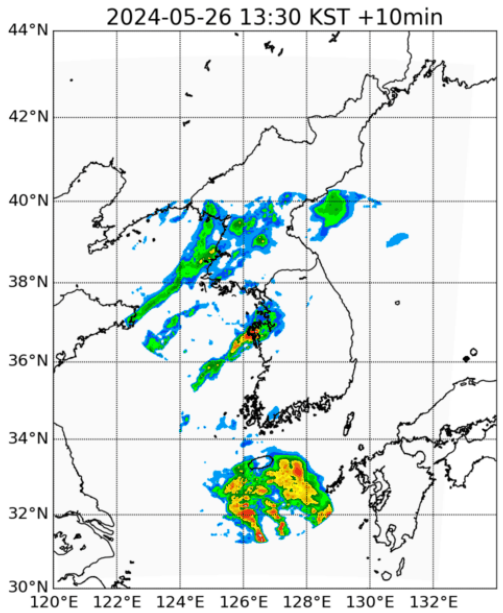
GT



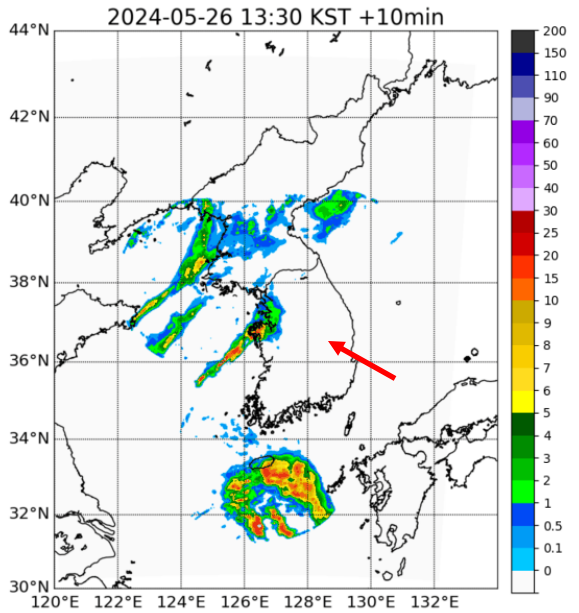
MeBT12_6hr



MeBT24_6hr



MeBT24_curr



Future work – Disaster labelled dataset

Input date
(i.e., 20210822)

disaster label
(1998-2021)

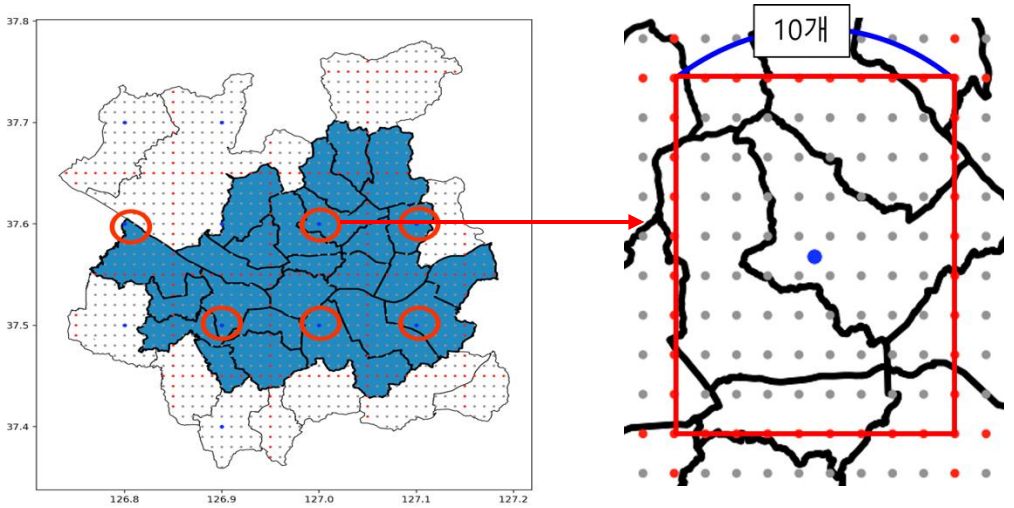
Landslide
Strong wind
Hail
Typhoon
Heavy snow
Heavy rain
Lightning
⋮

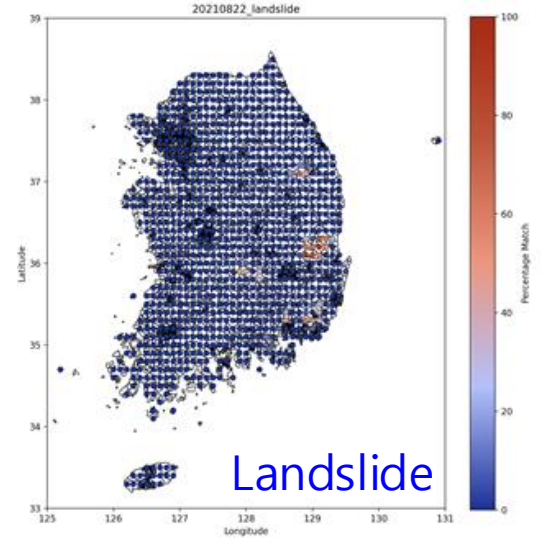
- **Current dataset**

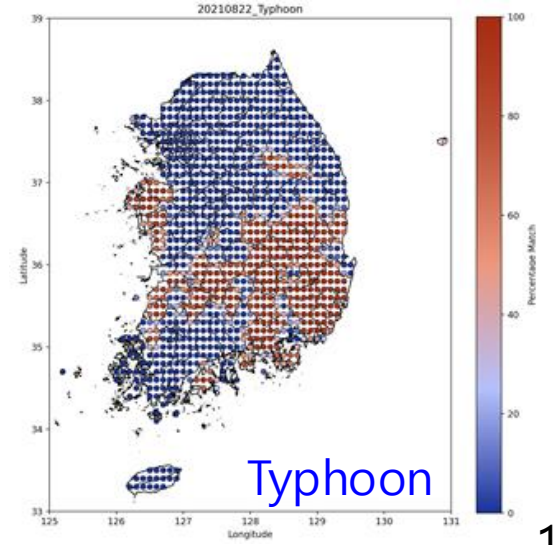
0: no disaster in the grid cell
1: disaster occurred in the grid cell

- **Upcoming dataset**

0: a low risk level
1: a very high risk of casualties
2: a very high risk of damage to buildings
3: a very high risk of infrastructure damage

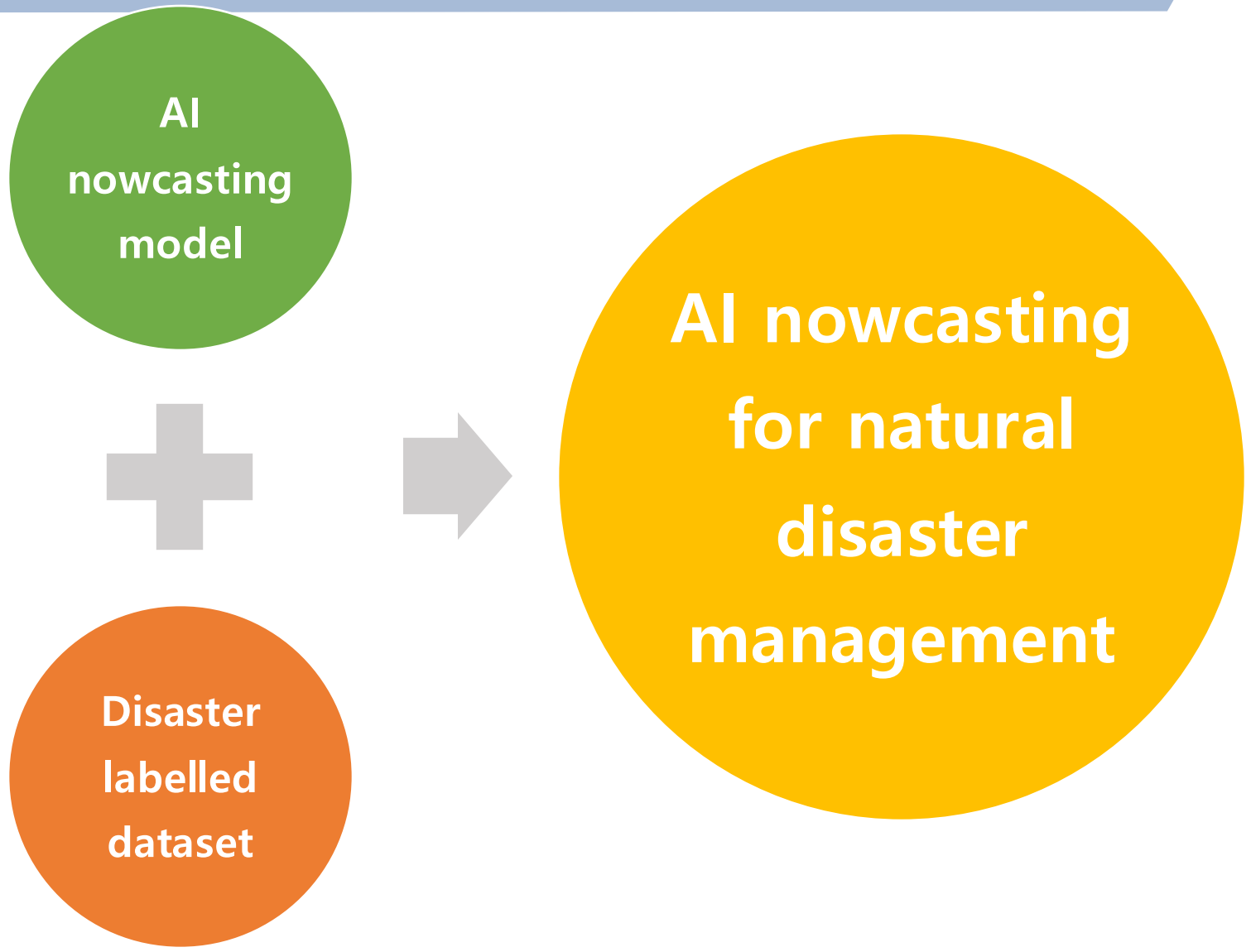






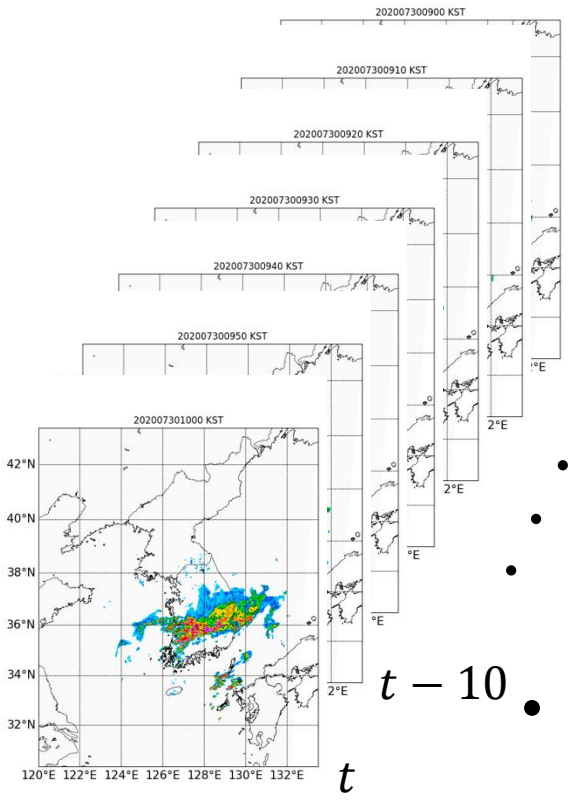
Future work – Disaster labelled dataset

- ✓ Developing an operational AI nowcasting model
- ✓ Fine-tuning the AI model for natural disasters
- ✓ Building an early-warning system using the AI model



Summary

✓ **Radar data**



$t - 360$

$t - 10$

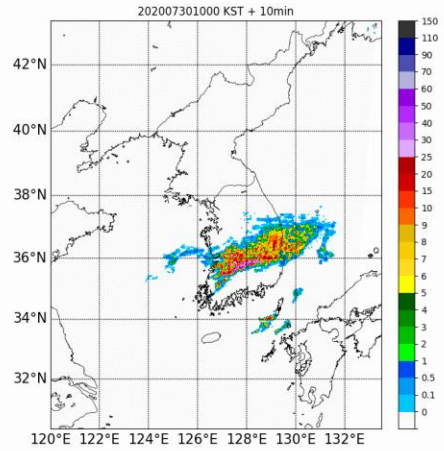
t

• **Data collection**

• **AI Model**

Operational Precipitation Nowcasting

✓ **Prediction**



• **Evaluation**

- qualitative analysis
- quantitative analysis

✓ **Heavy rainfall events**