Extreme Weather Nowcasting via Local Precipitation Pattern Prediction

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ICLR

Paper

Code & Resources

Introduction

Precipitation Nowcasting

- Climate change has increased the frequency of extreme, localized rainfall events, making accurate short-term forecasting critical.
- Numerical weather prediction models are too computationally expensive for real-time use.
- Although AI-based models have been developed, they often fail to capture extreme events due to data bias.

Radar Prediction

- Predicting future radar sequences from past observations.
- Evaluated using CSI and FSS on KMA, SEVIR, and MeteoNet datasets.

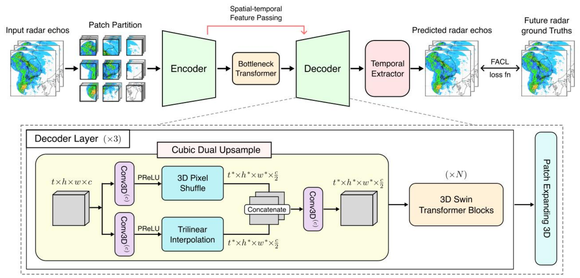
Challenging Features

- Extreme rainfall is short-lived and highly localized
- Requires capturing fine-grained radar structures.
- Needs flexible prediction across multiple time horizons.

Main Contribution

- Light yet highly accurate deterministic model.
- Flexible prediction horizons up to 6 hours with efficient fine-tuning.
- New dataset

Methods

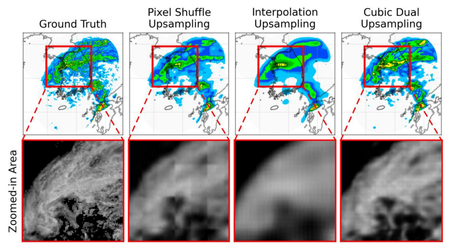


Window Attention

- 3D Swin Transformer with local window attention to capture localized spatiotemporal patterns.

Cubic Dual Upsample

- Combines pixel shuffle (detail) + interpolation (global trend).
- Reduces artifacts while preserving fine-grained structures.



Temporal Extractor

- Prediction horizon adjusted via Temporal Extractor fine-tuning.
- Enables flexible forecasting with low additional cost.

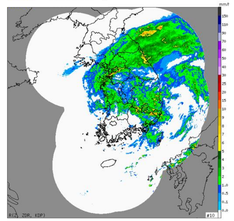
Training Loss

- Fourier Amplitude Correlation Loss

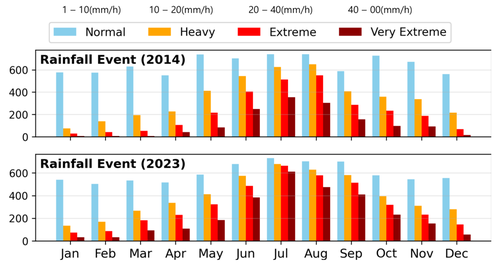
$$\mathrm{FACL}(X, \hat{X}, t) = \begin{cases} \mathrm{FAL}(X, \hat{X}), \text{if } p > P(t) \\ \mathrm{FCL}(X, \hat{X}), \text{otherwise} \end{cases}$$

New Dataset (KMA)

Radar Coverage in South Korea

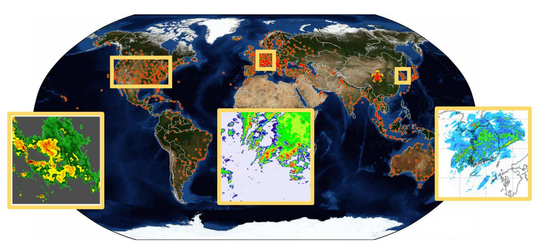


Property	Description
Image shape	2881 × 2305 pixels
Spatial resolution	500 meters per pixel
Temporal resolution	10 minutes
Reference center (pixel)	(1681, 1121)
Reference coordinate (geo)	38.0° N, 126.0° E
Pixel-geo projection method	Lambert Conformal Conic (LCC)
Data value (unit: 100 × dBZ)	
• Radar reflectivity	`value / 100`
• Outside observation area	`-30,000`
• No precipitation	`-25,000`
• Minimum measurable value	`-20,000`



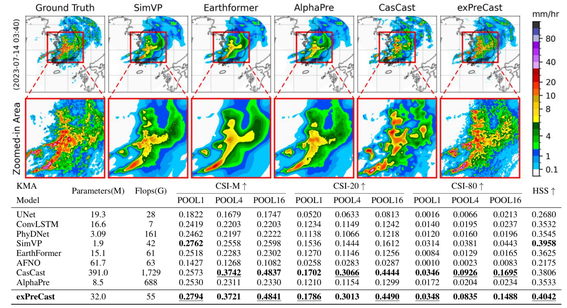
Korea Meteorological Administration (KMA)

- 10-year radar dataset with 10-minute intervals and 500 m resolution.
- Downscaled to 4 km resolution and cropped to a central 256 × 256 region.
- Train / Val / Test split: 2014–2021 / 2022 / 2023.

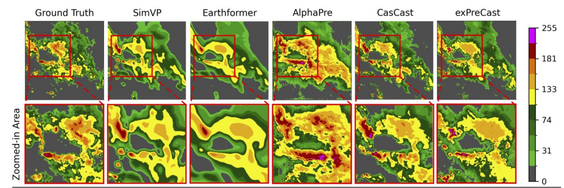


Experimental Results

Results: 1hour prediction

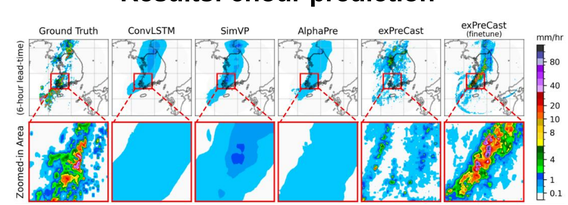


KMA Model	Parameters(M)	Flops(G)	CSI-M ↑ POOL1	CSI-M ↑ POOL4	CSI-M ↑ POOL16	CSI-20 ↑ POOL1	CSI-20 ↑ POOL4	CSI-20 ↑ POOL16	CSI-80 ↑ POOL1	CSI-80 ↑ POOL4	CSI-80 ↑ POOL16	HSS ↑
UNet	19.3	28	0.1822	0.1679	0.1747	0.0520	0.0633	0.0813	0.0016	0.0066	0.0213	0.2680
ConvLSTM	16.6	7	0.2419	0.2203	0.2203	0.1234	0.1149	0.1242	0.0140	0.0195	0.0237	0.3532
PhyDNet	3.09	161	0.2462	0.2197	0.2222	0.1138	0.1066	0.1218	0.0120	0.0160	0.0196	0.3545
SimVP	1.9	42	**0.2762**	0.2558	0.2598	0.1536	0.1444	0.1612	0.0314	0.0381	0.0443	**0.3958**
EarthFormer	15.1	61	0.2518	0.2283	0.2302	0.1270	0.1146	0.1256	0.0084	0.0129	0.0165	0.3625
AFNO	61.7	63	0.1427	0.1268	0.1082	0.0258	0.0283	0.0287	0.0010	0.0023	0.0083	0.2175
CasCast	391.0	1,729	0.2573	**0.3742**	**0.4837**	**0.1702**	**0.3066**	**0.4444**	**0.0346**	**0.0926**	**0.1695**	0.3806
AlphaPre	8.5	688	0.2530	0.2311	0.2330	0.1210	0.1154	0.1299	0.0172	0.0204	0.0234	0.3533
exPreCast	32.0	55	**0.2794**	**0.3721**	**0.4841**	**0.1786**	**0.3013**	**0.4490**	**0.0348**	**0.0835**	**0.1488**	**0.4042**



SEVIR Model	Parameters(M)	Flops(G)	CSI-M ↑ POOL1	CSI-M ↑ POOL4	CSI-M ↑ POOL16	CSI-181 ↑ POOL1	CSI-181 ↑ POOL4	CSI-181 ↑ POOL16	CSI-219 ↑ POOL1	CSI-219 ↑ POOL4	CSI-219 ↑ POOL16	HSS ↑
UNet	19.3	66	0.3848	0.3830	0.3964	0.1966	0.1926	0.2093	0.0848	0.0853	0.0998	0.4993
ConvLSTM	16.6	33	0.4102	0.4163	0.4475	0.2453	0.2525	0.2977	0.1322	0.1380	0.1734	0.5232
PhyDNet	13.7	701	0.4198	0.4226	0.4410	0.2526	0.2532	0.2782	0.1362	0.1359	0.1526	0.5311
SimVP	2.3	132	0.4153	0.4226	0.4530	0.2532	0.2604	0.3000	0.1338	0.1394	0.1685	0.5280
EarthFormer	15.1	257	**0.4310**	0.4319	0.4351	**0.2622**	0.2542	0.2562	0.1448	0.1409	0.1481	0.5411
AFNO	63.3	142	0.3613	0.3666	0.3692	0.1558	0.1539	0.1535	0.0859	0.0916	0.1007	0.4706
CasCast	392.9	4,567	**0.4401**	**0.4640**	**0.5525**	**0.2879**	**0.3179**	**0.3900**	**0.1851**	**0.2127**	**0.2841**	**0.5602**
AlphaPre	32.4	5,437	0.3996	0.4100	0.4180	0.2173	0.2315	0.2378	0.1081	0.1330	0.1459	0.4996
exPreCast	32.0	208	0.4179	**0.4527**	**0.5427**	0.2568	**0.2989**	**0.4104**	**0.1468**	**0.1859**	**0.2910**	**0.5430**

Results: 6hour prediction



KMA-6h Model	Parameters(M)	Flops(G)	CSI-M ↑ POOL1	CSI-M ↑ POOL4	CSI-M ↑ POOL16	CSI-20 ↑ POOL1	CSI-20 ↑ POOL4	CSI-20 ↑ POOL16	CSI-80 ↑ POOL1	CSI-80 ↑ POOL4	CSI-80 ↑ POOL16	HSS ↑
ConvLSTM	16.6	42	0.0748	0.0623	0.0572	0.0134	0.0137	0.0157	0.0013	0.0021	0.0026	0.1243
SimVP	3.5	97	0.0327	0.0260	0.0246	0.0066	0.0065	0.0081	0.0014	0.0023	0.0032	0.0595
AlphaPre*	287.2	4,898	0.0562	0.0451	0.0464	0.0061	0.0068	0.0095	0.0003	0.0004	0.0006	0.0865
exPreCast	33.6	229	0.0879	0.1271	0.2262	0.0323	0.0646	0.1542	0.0042	0.0130	0.0415	0.1486
exPreCast†	25.5	229	**0.1214**	**0.1572**	**0.2289**	**0.0510**	**0.0931**	**0.1708**	**0.0116**	**0.0282**	**0.0642**	**0.1987**