上海人工智能实验室
Shanghai Artificial Intelligence Laboratory

PostCast: Generalizable Postprocessing for Precipitation Nowcasting via Unsupervised Blurriness Modeling

Junchao Gong*, Siwei Tu*, WeidongYang*, Ben Fei†, Kun Chen, Wenlong Zhang,
Xiaokang Yang, Wanli Ouyang, Lei Bai

Motivation

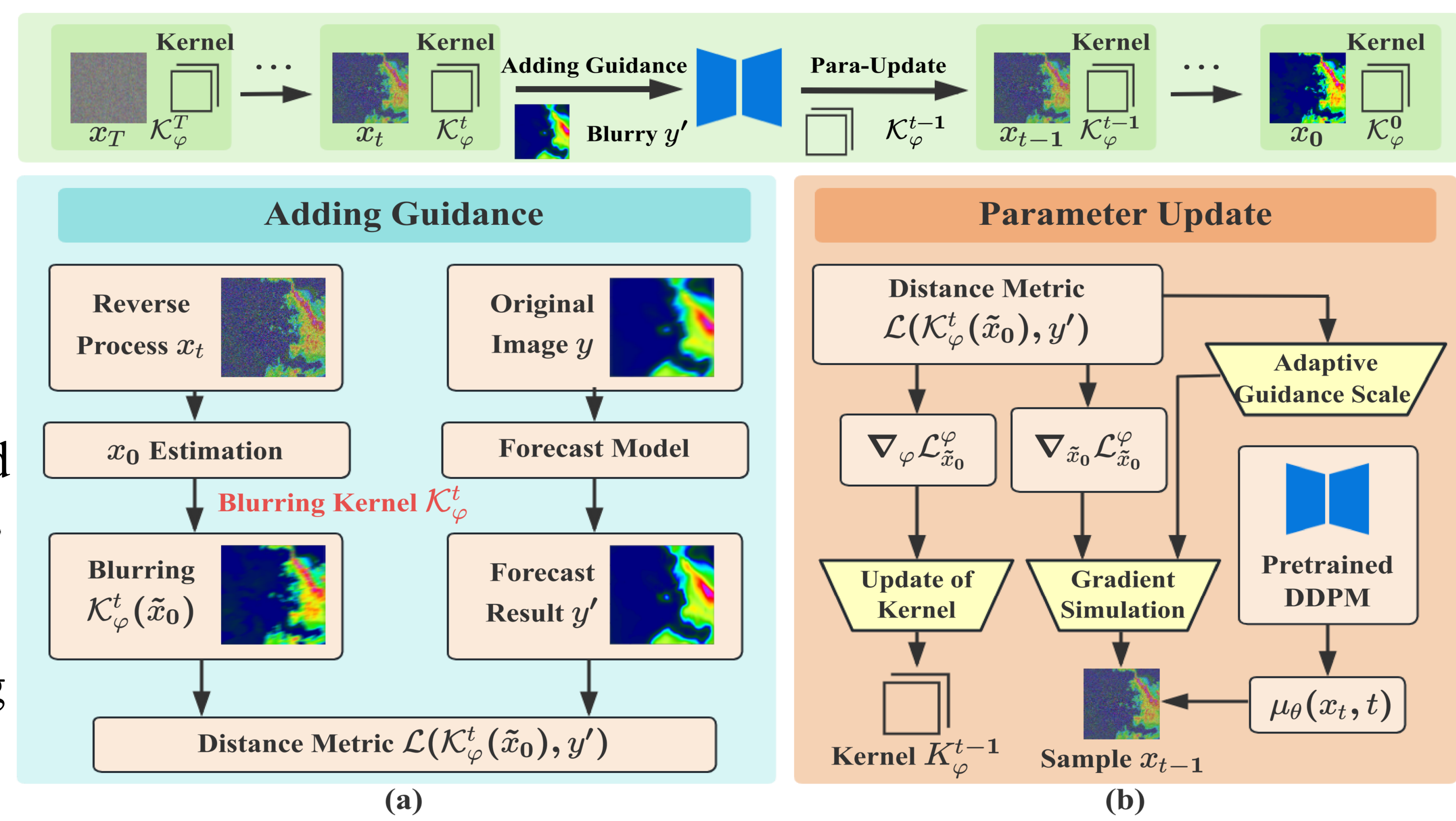
- Deterministic models and probabilistic models are combined together for precipitation nowcasting with both accurate global trend and clear local pattern.
- However, previous combination methods suffers from limited generalization to various datasets, lead times, and deterministic models.
- Furthermore, to train the probabilistic component, the blurry predictions and the corresponding ground truth are required to be provided in advance, making the training process of the probabilistic part exhausting.

Method

We propose a new pipeline composed of explicitly blurriness modeling with conv kernel and deblurring with an unconditional diffusion model guided by fuzzy prediction.

Blurriness modelling: blur modes in precipitation nowcasting with a unified formulation: $y' = conv(\mathcal{K}_{S,T,M}, y)$.

Unsupervised deblurring: fuzzy predictions could be tackled by solving the fuzzy inverse problem. This process is achieved by our Zero-shot blur estimation. Specifically, in each reverse diffusion step, we implement **Adding Guidance** and **Parameter Update** to guide the diffusion model generate radar images same as the fuzzy predictions after blur while estimate the parameters of blur kernel step by step. Besides, we propose an **auto-scale gradient guidance** strategy to adaptively set the guidance scale for each blurry mode.



Algorithm 1 Guided diffusion model with the guidance of blurry prediction y'. An unconditional diffusion model $\epsilon_\theta(x_t, t)$ fine-tuned on 5 datasets is given.

Input: Blurry prediction y', optimized blur kernel $\mathcal{K}$ with parameters φ, learning rate l, guidance scale s, distance metric $\mathcal{L}$.
Output: Deblurred prediction x_0 conditioned on y'. Sample x_T from $\mathcal{N}(0, I)$

1: **for all** t from T to 1 **do**
2: $\tilde{x}_0 = \frac{x_t}{\sqrt{\bar{\alpha}_t}} - \frac{\sqrt{1-\bar{\alpha}_t}\epsilon_\theta(x_t,t)}{\sqrt{\bar{\alpha}_t}}$
3: $\mathcal{L}_{\varphi,\tilde{x}_0} = \mathcal{L}(y', \mathcal{K}_\varphi^t(\tilde{x}_0))$
4: $s = -\frac{(x_t-\mu)^T g + C}{\mathcal{L}(\mathcal{K}_\varphi^t(\tilde{x}_0), y')}$
5: $\tilde{x}_0 \leftarrow \tilde{x}_0 - \frac{s(1-\bar{\alpha}_t)}{\sqrt{\bar{\alpha}_{t-1}}\beta_t} \nabla_{\tilde{x}_0} \mathcal{L}_{\varphi,\tilde{x}_0}$
6: $\tilde{\mu}_t = \frac{\sqrt{\bar{\alpha}_{t-1}}\beta_t}{1-\bar{\alpha}_t}\tilde{x}_0 + \frac{\sqrt{\bar{\alpha}_t}(1-\bar{\alpha}_{t-1})}{1-\bar{\alpha}_t} x_t$
7: $\tilde{\beta}_t = \frac{1-\bar{\alpha}_{t-1}}{1-\bar{\alpha}_t}\beta_t$
8: Sample x_{t-1} from $\mathcal{N}(\tilde{\mu}_t, \tilde{\beta}_t I)$
9: $\varphi \leftarrow \varphi - l\nabla_\varphi \mathcal{L}_{\varphi,\tilde{x}_0}$
10: **end for**
11: **return** x_0

Experimental results

- Improved precipitation nowcasting skill

Model	SEVIR					HKO7					TAASRAD19				
	P1	P4	P16	HSS↑	POD↑	P1	P4	P16	HSS↑	POD↑	P1	P4	P16	HSS↑	POD↑
TAU	0.008	0.014	0.028	0.383	0.372	0.051	0.064	0.104	0.390	0.332	0.010	0.017	0.021	0.276	0.220
+ours	0.043	0.074	0.163	0.402	0.438	0.060	0.127	0.289	0.386	0.389	0.044	0.072	0.127	0.300	0.311
PredRNN	0.013	0.014	0.017	0.378	0.358	0.006	0.008	0.018	0.352	0.304	0.008	0.010	0.012	0.237	0.178
+ours	0.059	0.083	0.161	0.397	0.432	0.050	0.110	0.266	0.350	0.371	0.038	0.064	0.138	0.279	0.275
SimVP	0.015	0.016	0.024	0.389	0.385	0.042	0.049	0.067	0.409	0.358	0.000	0.000	0.002	0.242	0.181
+ours	0.045	0.069	0.140	0.409	0.462	0.054	0.116	0.264	0.385	0.409	0.021	0.035	0.051	0.298	0.275
EarthFormer	0.032	0.024	0.023	0.374	0.357	0.025	0.025	0.035	0.390	0.334	0.019	0.021	0.028	0.266	0.204
+ours	0.045	0.070	0.131	0.403	0.427	0.066	0.125	0.257	0.392	0.395	0.044	0.067	0.143	0.286	0.283
DiffCast	0.049	0.070	0.186	0.362	0.378	0.061	0.113	0.255	0.385	0.375	0.044	0.076	0.174	0.267	0.260
CasCast	0.039	0.067	0.156	0.335	0.422	0.054	0.108	0.235	0.343	0.454	0.040	0.064	0.128	0.221	0.301
DGMR	0.003	0.010	0.062	0.122	0.235	0.018	0.055	0.210	0.210	0.182	0.015	0.038	0.120	0.097	0.091
STRPM	0.007	0.023	0.060	0.307	0.296	0.010	0.027	0.078	0.263	0.196	0.005	0.016	0.054	0.186	0.138
DGP	0.020	0.042	0.070	0.372	0.355	0.039	0.083	0.187	0.372	0.328	0.018	0.041	0.094	0.238	0.196

- Zero-shot generalization on other datasets

Model	SCWDS CAP30					SCWDS CR					MeteoNet				
	P1	P4	P16	HSS	POD	P1	P4	P16	HSS	POD	P1	P4	P16	HSS	POD
TAU	0.038	0.042	0.064	0.312	0.280	0.082	0.075	0.082	0.413	0.384	0.001	0.003	0.016	0.272	0.240
+CasCast	0.067	0.102	0.224	0.306	0.315	0.101	0.145	0.258	0.380	0.377	**0.029**	**0.067**	0.128	0.271	0.294
+DiffCast	0.023	0.050	0.166	0.157	0.235	0.051	0.101	0.245	0.232	**0.554**	0.006	0.015	0.063	0.079	0.065
+ours	**0.075**	**0.126**	**0.269**	**0.345**	**0.428**	**0.143**	**0.214**	**0.338**	**0.444**	0.549	0.024	0.059	**0.182**	**0.288**	**0.344**
PredRNN	0.003	0.004	0.008	0.239	0.203	0.040	0.043	0.066	0.351	0.323	0.000	0.000	0.002	0.230	0.190
+CasCast	0.035	0.056	0.129	0.252	0.231	0.086	0.139	0.283	0.337	0.390	0.010	0.030	0.101	0.249	0.238
+DiffCast	0.017	0.035	0.102	0.157	0.235	0.066	0.105	0.230	0.349	0.341	0.006	0.019	0.076	0.241	0.215
+ours	**0.060**	**0.126**	**0.267**	**0.331**	**0.351**	**0.140**	**0.206**	**0.315**	**0.405**	**0.485**	**0.022**	**0.050**	**0.148**	**0.283**	**0.298**
SimVP	0.025	0.026	0.035	0.312	0.276	0.056	0.046	0.041	0.410	0.373	0.000	0.000	0.002	0.281	0.245
+CasCast	0.069	0.111	0.226	0.314	0.319	0.098	0.134	0.242	0.382	0.364	0.030	0.053	**0.149**	0.282	0.305
+DiffCast	0.024	0.044	0.129	0.224	0.201	0.047	0.071	0.169	0.295	0.280	0.017	0.037	0.105	0.240	0.216
+ours	**0.085**	**0.136**	**0.255**	**0.367**	**0.436**	**0.140**	**0.205**	**0.296**	**0.459**	**0.545**	**0.025**	**0.054**	0.147	**0.316**	**0.391**
EarthFormer	0.021	0.024	0.036	0.298	0.258	0.072	0.065	0.063	0.417	0.406	0.000	0.003	0.008	0.259	0.219
+CasCast	0.050	0.089	0.190	0.296	0.287	0.100	0.130	0.223	0.381	0.383	**0.019**	0.055	0.159	0.266	0.265
+DiffCast	0.041	0.071	0.175	0.299	0.278	0.101	0.144	0.268	0.407	0.417	0.009	0.029	0.096	0.263	0.243
+ours	**0.070**	**0.117**	**0.241**	**0.350**	**0.404**	**0.141**	**0.211**	**0.326**	**0.444**	**0.570**	**0.019**	**0.058**	**0.164**	**0.287**	**0.320**
DGMR	0.018	0.048	0.160	0.161	0.153	0.039	0.090	0.240	0.207	0.208	0.019	0.057	0.192	0.123	0.131
STRPM	0.014	0.049	0.160	0.234	0.197	0.029	0.080	0.201	0.296	0.264	0.014	0.046	0.145	0.192	0.155
DGP	0.027	0.059	0.111	0.294	0.258	0.071	0.083	0.099	0.409	0.397	0.037	0.082	0.186	0.250	0.218

- Visualization with different lead times and datasets