Github Repository, Please access: https://github.com/DrHoisu/Channel_Mixer_Layer

Channel Mixer Layer: Multimodal Fusion Towards Machine Reasoning for Spatiotemporal Predictive Learning of Ionospheric Total Electron Content

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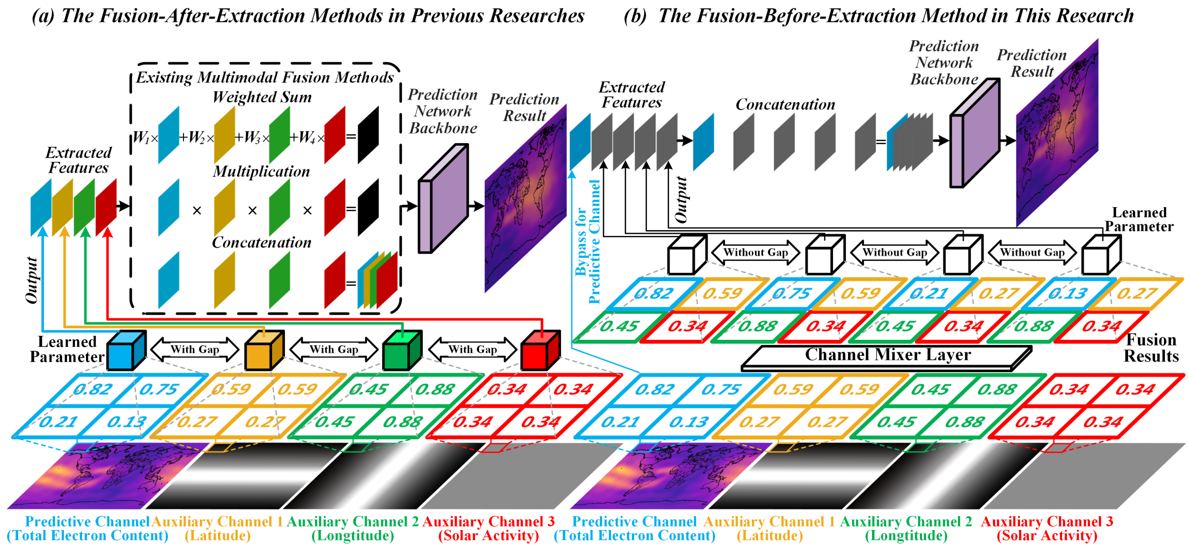
open issues 0

Stars 1

📘Dataset | 🚀Model Zoo

Introduction

This repository is the official implementation of our *Space Weather* journal paper with the same above title. Channel Mixer Layer is a multimodal fusion framework for spatiotemporal predictive learning, which aims to improve the prediction accuracy of predictive channel by inputting auxiliary channel. The program deployment is based on OpenSTL, a framework of graphic prediction without auxiliary channel input. We improve it by adding the machine reasoning capability. Note that OpenSTL used in this program is PyTorch version instead of the newest Pytorch-Lightning version due to the fixed learning rate bug when this research began. Currently, Channel Mixer Layer only support our iono_electron dataset because most datasets for video prediction do **not** have auxiliary data input.



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Overview

▼ Hardware Recommendation

- `RAM memory` > 16 GB
- `GPU` >= Nvidia RTX 3090 with the VRAM larger than 24 GB

▼ Code Structures

- `scripts/` contains experiment execution scripts.
- `openstl/api` contains an experiment runner.
- `openstl/core` contains core training plugins and metrics.
- `openstl/datasets` contains datasets and dataloaders.
- `openstl/methods/` contains training methods for various video prediction methods.
- `openstl/models/` contains the main network architectures of various video prediction methods.
- `openstl/modules/` contains network modules and layers.
- `tools/` contains the executable python files `tools/train.py` and `tools/test.py` with possible arguments for training, validating, and testing pipelines.

Installation

This project has provided an environment setting file of conda, users can easily reproduce the environment by the following commands (type in one by one):

```
git clone https://github.com/DrHoisu/Channel_Mixer_Layer
cd Channel_Mixer_Layer
conda env create -f environment.yml
conda activate Mixer
python setup.py develop
```

Please refer to install.md for more detailed instructions.

Iono_Electron Data-set

Download Iono_Electron Data-set from website or using the following command:

```
bash tools/prepare_data/download_iono.sh
```

Pretrained Model

Download pretrained models from website or using the following command:

```
bash tools/prepare_data/download_pretrained_model.sh
```

Training and Testing

Please see get_started.md for the basic usage. All training and testing commands are listed under `scripts/` directory Here is an example to evaluate the prediction accuracy of the pretrained models with different input channel number and different multimodal fusion methods.

```
bash scripts/iono/convlstm/convlstm.sh
bash scripts/iono/e3dlstm/e3dlstm.sh
bash scripts/iono/mau/mau.sh
bash scripts/iono/mim/mim.sh
bash scripts/iono/predrnn/predrnn.sh
bash scripts/iono/predrnnpp/predrnnpp.sh
bash scripts/iono/predrnnv2/predrnnv2.sh
bash scripts/iono/simvp/simvp.sh
bash scripts/iono/tau/tau.sh
```

Table 1 The quantitative performance comparison for the different network backbones, multimodal fusion methods and input channel number C_{in}. The computational complexity is evaluated by parameter number (Param.), Floating-point Operations Per Second (Flops) and inference speed. The prediction accuracy is evaluated by mean squared error (MSE), mean absolute error (MAE) and root mean square error (RMSE) during low/high solar activity (LSA/HSA) periods.

Fusion-(Backbone)	C_{in}	Param /M	Flops /G	Speed /fps	MSE	MAE/TECU		RMSE (Gain)
						LSA	HSA	
(LSTM)	1	283.6	5035	5	374.11	2.16	5.18	3.76 (+0%)
(GRU)	1	212.7	3786	7	361.36	1.97	5.06	3.69 (+0%)
(E3D-LSTM)	1	53.15	301	22	173.51	1.11	3.54	2.56 (+0%)
(MAU)	1	4.72	67.13	242	153.97	1.10	3.28	2.41 (+0%)
concatenate-	4	4.72	67.19	235	152.55	1.12	3.27	2.40(+0.4%)
concatenate-	9	4.72	67.28	215	139.90	1.08	3.11	2.30(+4.6%)
concatenate-	16	4.72	67.42	188	120.78	1.05	2.86	2.14(+11.2%)
(PredRNN)	1	23.84	456	65	152.59	1.10	3.26	2.40 (+0%)
action-	4	24.16	461	64	198.29	1.25	3.82	2.74(-14.2%)
concatenate-	4	24.92	476	62	172.22	1.21	3.49	2.55(-6.3%)
mixer-	**4**	**25.27**	**483**	**61**	**160.18**	**1.15**	**3.35**	**2.46(-2.5%)**
action-	9	24.51	468	64	277.31	1.47	4.17	3.24(-35.0%)
concatenate-	9	26.71	511	58	157.43	1.16	3.37	2.44(-1.7%)
mixer-	**9**	**27.06**	**518**	**57**	**155.98**	**1.16**	**3.32**	**2.43(-1.3%)**
action-	16	25.06	482	61	403.47	2.06	5.51	3.91(-62.9%)
concatenate-	16	29.22	558	53	138.65	1.11	3.10	2.29(+4.6%)
mixer-	**16**	**29.57**	**565**	**52**	**133.43**	**1.05**	**2.98**	**2.24(+6.7%)**
(TAU)	1	48.24	22.54	341	151.06	1.09	3.26	2.39 (+0%)
concatenate-	4	48.24	22.61	331	150.04	1.12	3.23	2.38(+0.4%)
mixer-	**4**	**48.24**	**22.61**	**326**	**148.83**	**1.11**	**3.20**	**2.37(+0.8%)**
concatenate-	9	48.24	22.83	302	142.98	1.04	3.18	2.33(+2.5%)
mixer-	**9**	**48.24**	**22.83**	**296**	**139.03**	**1.05**	**3.11**	**2.29(+4.2%)**
concatenate-	16	48.25	23.08	264	126.33	1.02	2.96	2.19(+8.4%)
mixer-	**16**	**48.25**	**23.11**	**254**	**121.54**	**0.99**	**2.89**	**2.14(+10.5%)**
(SimVP)	1	50.53	23.32	335	149.51	1.05	3.24	2.38 (+0%)
concatenate-	4	50.53	23.43	327	153.37	1.12	3.29	2.41(-1.3%)
mixer-	**4**	**50.53**	**23.46**	**322**	**152.96**	**1.11**	**3.28**	**2.40(-0.8%)**
concatenate-	9	50.53	23.61	298	145.15	1.08	3.19	2.34(+1.7%)
mixer-	**9**	**50.53**	**23.64**	**291**	**141.52**	**1.05**	**3.14**	**2.31(+2.9%)**
concatenate-	16	50.54	23.86	253	125.16	1.00	2.94	2.18(+8.4%)
mixer-	**16**	**50.54**	**23.90**	**241**	**120.74**	**0.98**	**2.90**	**2.13(+10.5%)**

Fusion-(Backbone)	C_{in}	Param /M	Flops /G	Speed /fps	MSE	MAE/TECU		RMSE (Gain)
						LSA	HSA	
(ConvLSTM)	1	15.08	223	136	194.81	1.25	3.75	2.71 (+0%)
concatenate-	4	15.70	235	132	199.78	1.28	3.79	2.75(-1.5%)
mixer-	**4**	**15.90**	**239**	**130**	**174.78**	**1.10**	**3.51**	**2.57(+5.2%)**
concatenate-	9	16.72	255	121	166.25	1.12	3.37	2.51(+7.4%)
mixer-	**9**	**16.93**	**258**	**118**	**165.87**	**1.09**	**3.38**	**2.50(+7.8%)**
concatenate-	16	18.16	282	105	147.21	1.08	3.20	2.36(+12.9%)
mixer-	**16**	**18.36**	**286**	**101**	**135.12**	**1.02**	**3.03**	**2.26(+16.6%)**
(PredRNNv2)	1	23.86	458	63	152.01	1.07	3.25	2.40 (+0%)
action-	4	24.18	463	62	167.69	1.15	3.34	2.52(-5.0%)
concatenate-	4	24.93	479	60	156.59	1.10	3.35	2.43(-1.3%)
mixer-	**4**	**25.29**	**486**	**59**	**153.11**	**1.11**	**3.31**	**2.41(-0.4%)**
action-	9	24.53	470	61	237.44	1.36	3.92	2.99(-24.6%)
concatenate-	9	26.72	513	56	151.19	1.12	3.25	2.39(+0.4%)
mixer-	**9**	**27.08**	**520**	**54**	**150.28**	**1.10**	**3.23**	**2.38(+0.8%)**
action-	16	25.08	485	59	318.57	1.67	4.46	3.47(-44.6%)
concatenate-	16	29.23	561	51	122.86	1.01	2.88	2.16(10.0%)
mixer-	**16**	**29.59**	**568**	**51**	**118.83**	**0.99**	**2.83**	**2.12(+11.7%)**
(MIM)	1	38.20	711	43	158.97	1.12	3.32	2.45 (+0%)
concatenate-	4	39.28	731	42	158.27	1.11	3.32	2.45(+0%)
mixer-	**4**	**39.63**	**738**	**41**	**158.76**	**1.14**	**3.30**	**2.45(+0%)**
concatenate-	9	41.07	766	38	148.57	1.09	3.19	2.37(+3.3%)
mixer-	**9**	**41.42**	**773**	**37**	**145.33**	**1.08**	**3.18**	**2.34(4.5%)**
concatenate-	16	43.58	814	34	126.37	1.01	2.93	2.19(+10.6%)
mixer-	**16**	**43.93**	**821**	**32**	**118.72**	**0.98**	**2.90**	**2.12(+13.5%)**
(PredRNN++)	1	38.58	675	46	153.12	1.05	3.26	2.41 (+0%)
concatenate-	4	39.66	695	44	150.21	1.05	3.24	2.38(+1.2%)
mixer-	**4**	**40.01**	**702**	**43**	**148.83**	**1.10**	**3.21**	**2.37(+1.7%)**
concatenate-	9	41.45	730	41	144.20	1.11	3.16	2.34(+2.9%)
mixer-	**9**	**41.81**	**737**	**40**	**141.22**	**1.05**	**3.12**	**2.31(+4.1%)**
concatenate-	16	43.96	778	35	118.45	0.97	2.74	2.12(+12.0%)
mixer-	**16**	**44.32**	**785**	**34**	**111.68**	**0.94**	**2.63**	**2.05(+14.9%)**

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Overview of Model Zoo

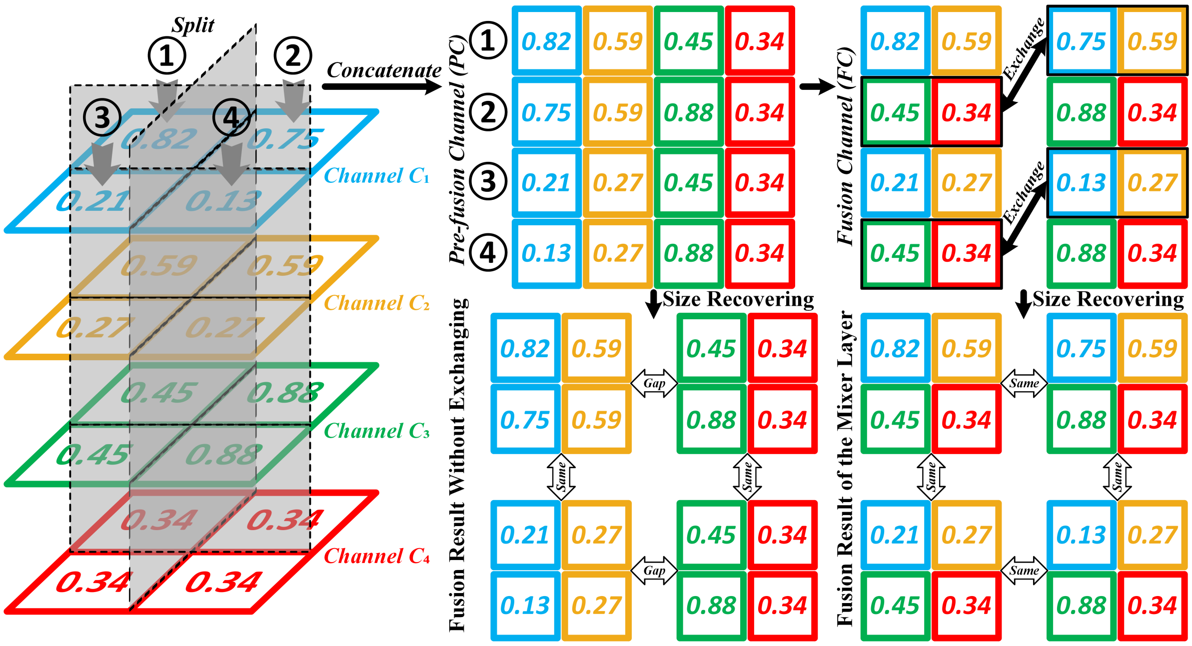
- Spatiotemporal Prediction Methods.
  - ▼ Currently supported methods
    - [x] ConvLSTM (NeurIPS'2015)
    - [x] PredNet (ICLR'2017)
    - [x] PredRNN (NeurIPS'2017)
    - [x] PredRNN++ (ICML'2018)
    - [x] E3D-LSTM (ICLR'2018)
    - [x] MIM (CVPR'2019)
    - [x] CrevNet (ICLR'2020)
    - [x] PhyDNet (CVPR'2020)
    - [x] MAU (NeurIPS'2021)
    - [x] PredRNN.V2 (TPAMI'2022)

- [x] SimVP (CVPR'2022)
- [x] SimVP.V2 (ArXiv'2022)
- [x] TAU (CVPR'2023)
- [x] DMVFN (CVPR'2023)

You can understand our Channel Mixer Layer more intuitively by the following command:

```
python Understand_Mixer.py
```

our Channel Mixer Layer is deployed as shown by the following process:



Visualization

We present visualization examples of ConvLSTM below. For more detailed information, please refer to the visualization.

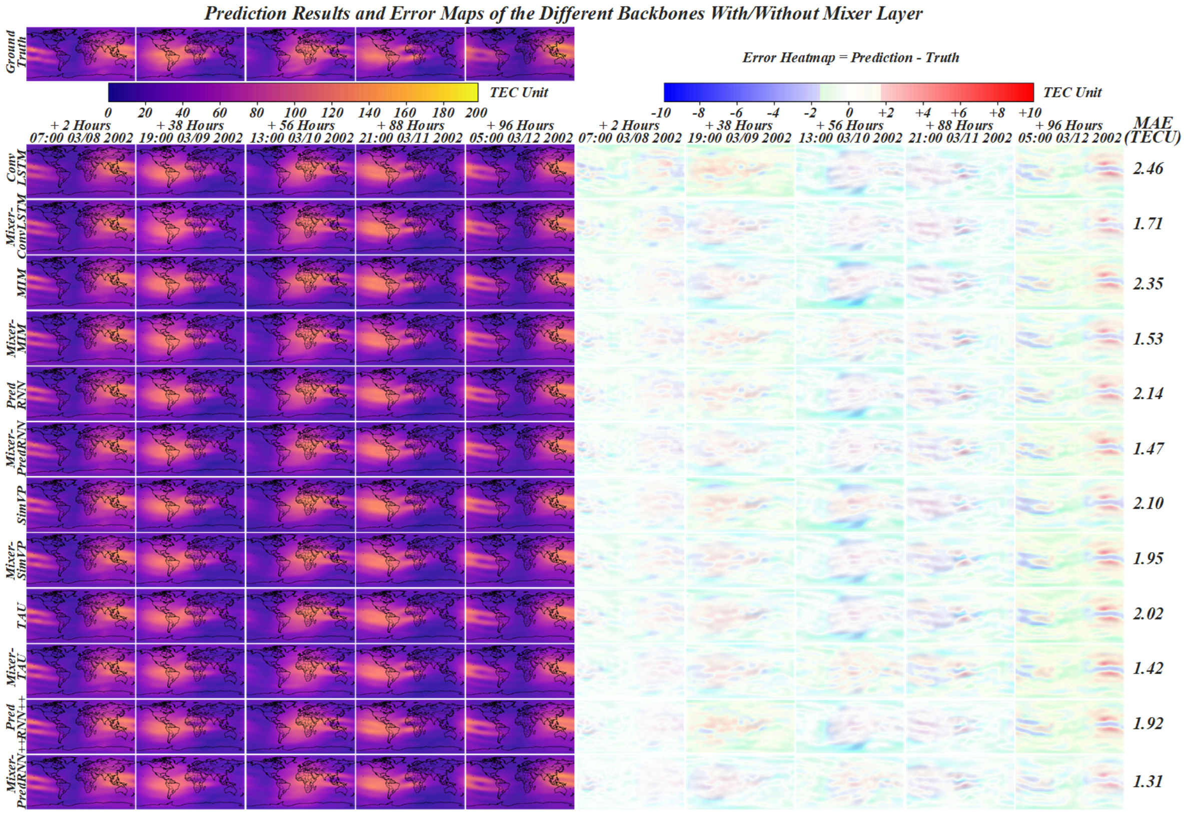
The visualization of 1-channel graphic prediction with ConvLSTM model for the No.125 global TEC sequence is running by the following command:

```
python tools/visualizations/vis_video.py -d iono -w
work_dirs/iono/convlstm/1channel --index 125 --save_dirs
visualization/iono/convlstm/1channel/
```

The visualization of 16-channel multimodal fusion prediction with Mixer-ConvLSTM model for the No.125 global TEC sequence is running by the following command:

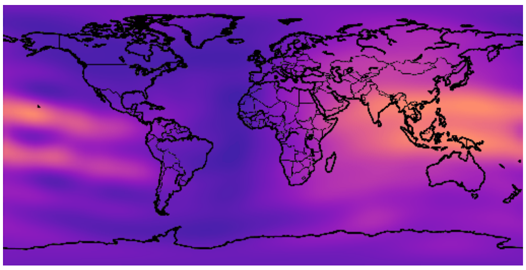
```
python tools/visualizations/vis_video.py -d iono -w
work_dirs/iono/convlstm/mix_16channel --index 125 --save_dirs
visualization/iono/convlstm/mix_16channel/
```

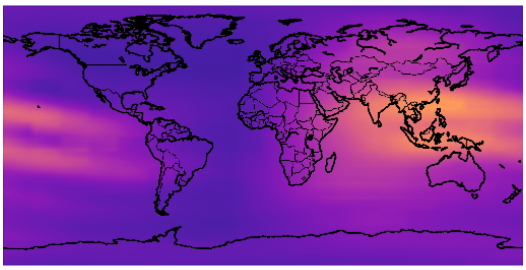
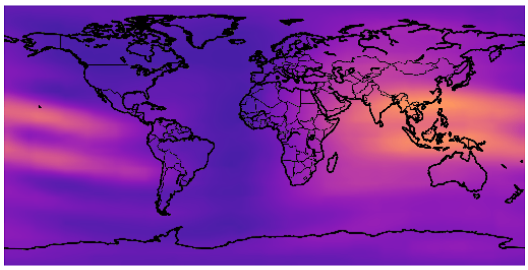
Static Comparison:

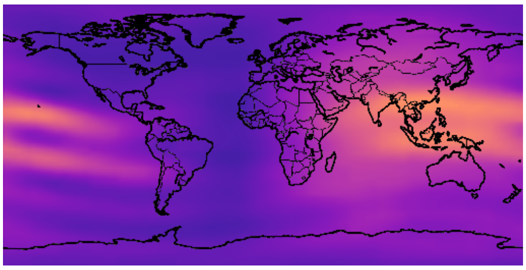
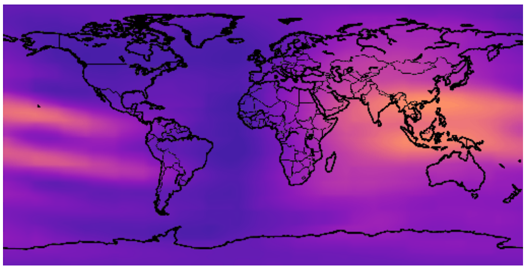


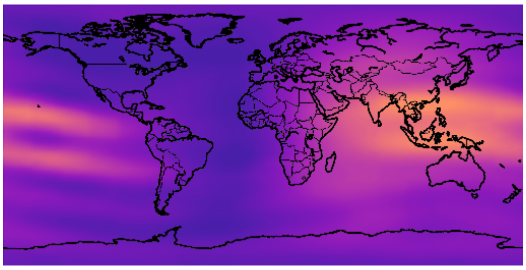
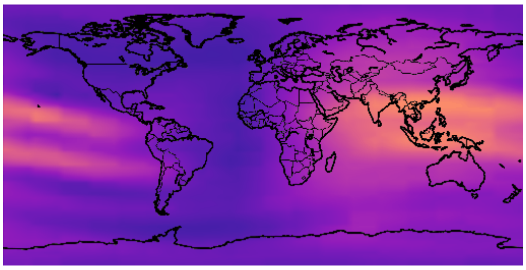
Dynamic Comparison:

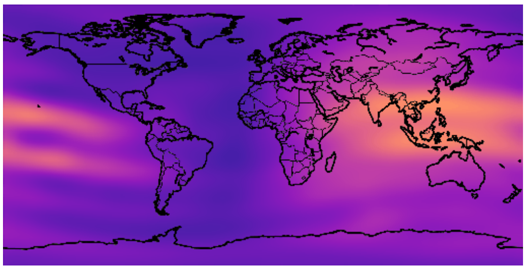
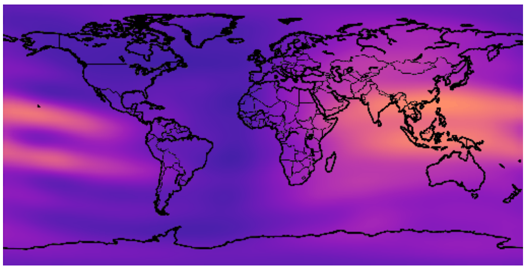
Ground Truth

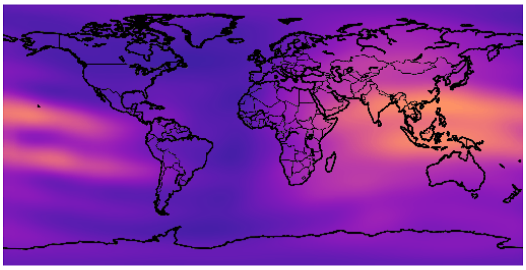
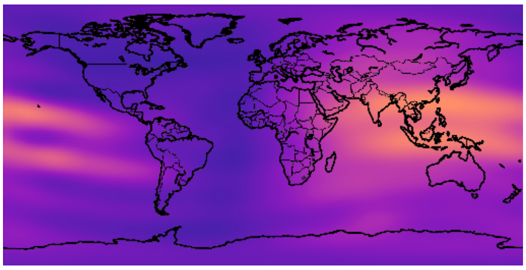


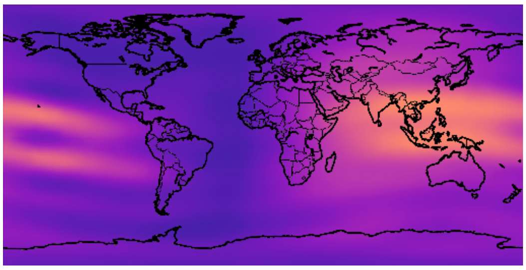
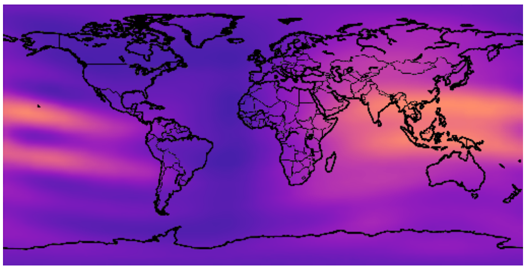
ConvLSTM Result	Mixer-ConvLSTM Result
	

MIM Result	Mixer-MIM Result
	

PredRNN Result	Mixer-PredRNN Result
	

SimVP Result	Mixer-SimVP Result
	

TAU Result	Mixer-TAU Result
	

PredRNN++ Result	Mixer-PredRNN++ Result
	

Citation

If you are interested in our repository or our paper, please cite the following paper:

Text Format

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