Deep learning for improved global precipitation in numerical weather prediction systems

Virtual Centre on Artificial Intelligence (AI)/ Machine Learning (ML)/ Deep Learning (DL)

Introduction

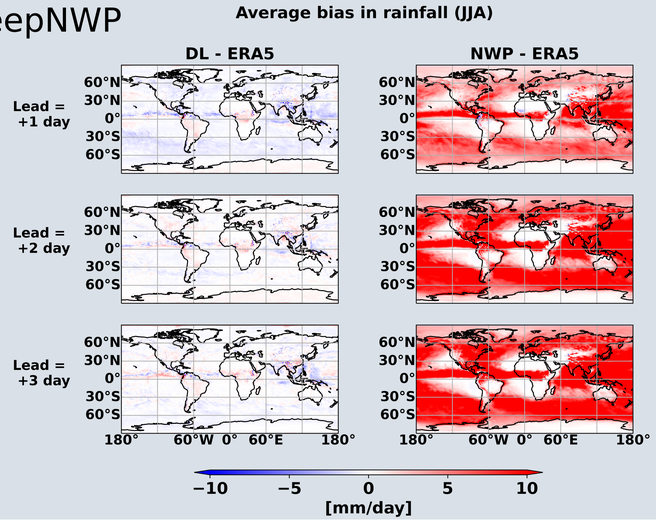
- Precipitation drives the hydroclimate of Earth and its spatiotemporal changes ona day to day basis have one of the most notable socioeconomic impacts.
- Largebiases however exist in the precipitation products of numerical weather prediction models.
- Hybrid methodology using NWP outputs as inputs to the deep learningbased refinement tool offer an attractive means taking advantage of both NWP andstate of the art deep learning algorithms.
- Augmenting the output from a well-knownNWP model: Coupled Forecast System ver.2 (CFSv2) with deep learning for thefirst time, we demonstrate a hybrid model capability (DeepNWP) which showssubstantial skill improvements for short-range global precipitation at 1-, 2- and3-days lead time.
- To achieve this hybridization, we address the sphericity of theglobal data by using modified DLWP-CS architecture which transforms all thefields to cubed-sphere projection. The dynamical model outputs correspondingto precipitation and surface temperature are ingested to a UNET for predictingthe target ground truth precipitation.
- While the dynamical model CFSv2 shows a bias in the range of +5 to +7 mm/day over land, the multivariate deep learningmodel reduces it to -1 to +1 mm/day over global land areas.
- We validate theresults by taking examples from Hurricane Katrina in 2005, Hurricane Ivan in 2004,Central European floods in 2010, China floods in 2010, India floods in 2005 andthe Myanmar cyclone Nargis in 2008.

Other Details

GPU system used: NVIDIA A100

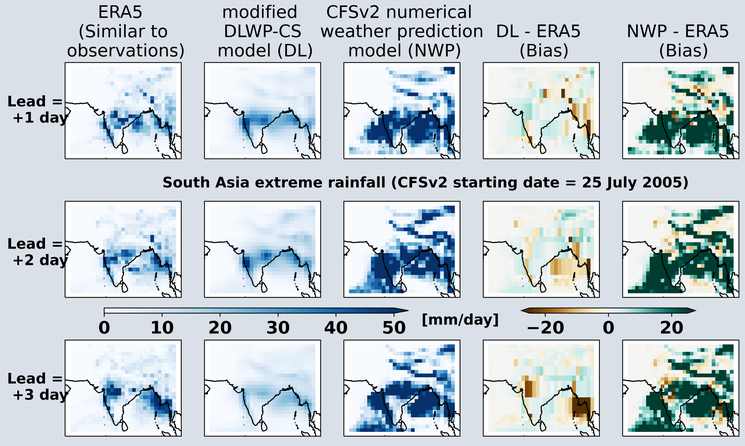
Ongoing work: Develop a product using Google Earth Engine based cloud computing for DeepNWP, increasing the spatial resolution and downscaling

DeepNWP

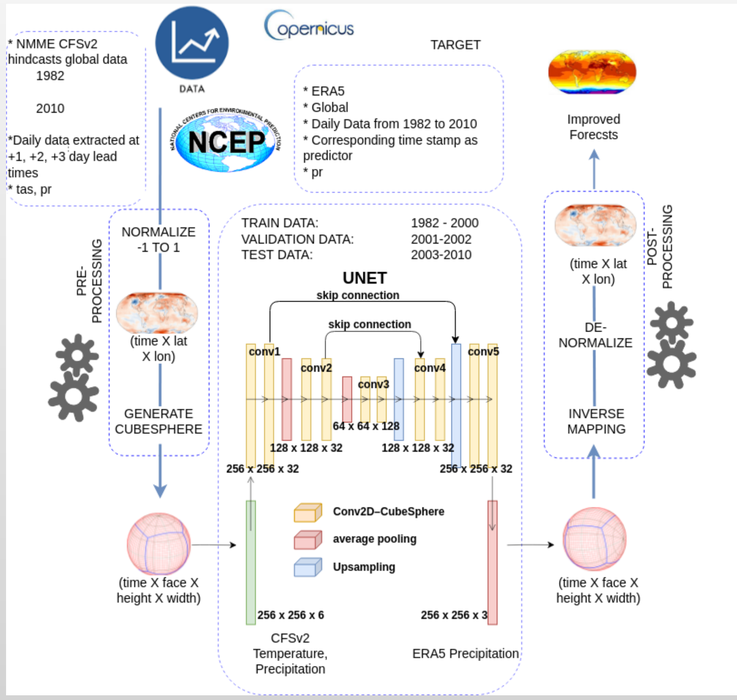


Season	Lead = 1 day (mm/day)		Lead = 2 day (mm/day)		Lead = 3 day (mm/day)	
	DL - ERA5	CFSv2 - ERA5	DL - ERA5	CFSv2 - ERA5	DL - ERA5	CFSv2 - ERA5
DJF	**-0.3**	3.827	**0.022**	7.66	**-0.158**	7.657
MAM	**-0.282**	3.834	**0.032**	7.811	**-0.11**	7.89
JJA	**-0.334**	3.97	**-0.02**	8.102	**-0.115**	8.239
SON	**-0.299**	3.954	**0**	7.95	**-0.148**	7.972

DeepNWP performance on 2005 heavy rain



Deep learning augmented NWP schematic



Case Studies

Events	Lead = 1 day (mm/day)		Lead = 2 day (mm/day)		Lead = 3 day (mm/day)	
	DL - ERA5	CFSv2 - ERA5	DL - ERA5	CFSv2 - ERA5	DL - ERA5	CFSv2 - ERA5
Hurricane Katrina	**-0.345**	8.839	**0.453**	12.18	**-0.811**	10.227
Hurricane Ivan	**-0.22**	8.466	**-0.036**	13.48	**-1.485**	13.135
Cyclone Nargis	**-5.37**	21.151	**-1.245**	43.845	**2.338**	47.233
Europe Floods	**-0.2**	6.654	**-0.015**	8.134	**0.12**	6.94
China Floods	**-0.17**	11.233	**0.465**	18.903	**-0.48**	16.877
India flood	**0.003**	17.321	**0.139**	25.297	**-0.749**	20.259

Publications

A modified deep learning weather prediction using cubed sphere for global precipitation. Singh et al, *Frontiers in Climate 2023*

Short-range forecasts of global precipitation using deep learning-augmented numerical weather prediction. Singh et al, *NeurIPS 2022*

Artificial intelligence and machine learning in earth system sciences with special reference to climate science and meteorology in South Asia. Singh et al, *Current Science 2022*

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