Tackling Climate Change with Machine Learning, NeurIPS 2022

Generating physically-consistent, high-resolution climate data

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IBM

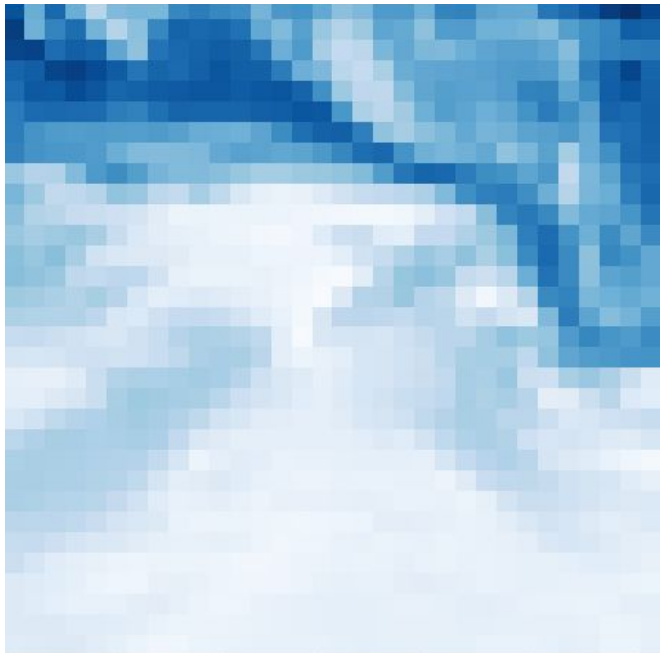
Mila

Intro

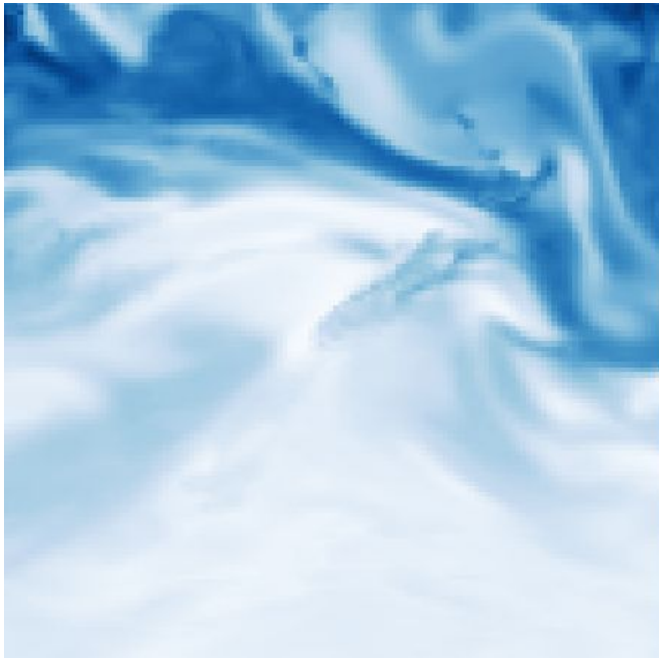
Goal

Increasing climate data's resolution

Low-resolution (LR) input



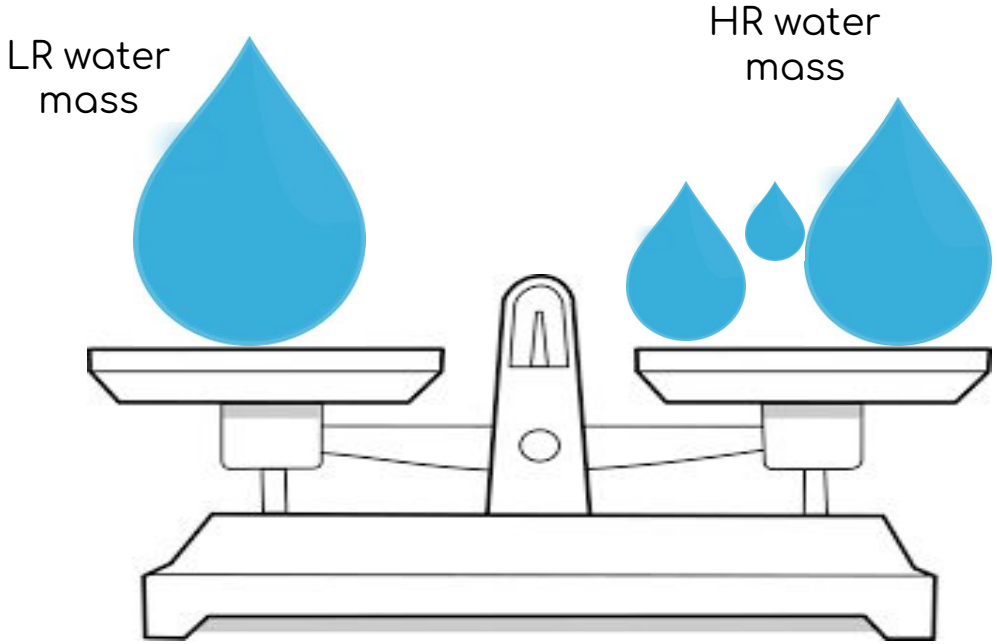
High-resolution (HR) target



Goal

Increasing climate data's resolution ...

while obeying laws of physics



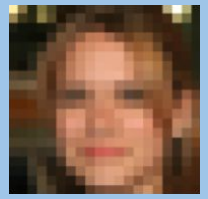
Terminology

Machine Learning

super-resolution

upsampling/downsampling

standard images



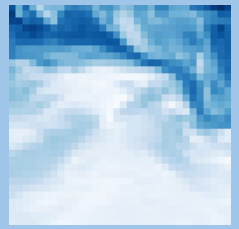
vs

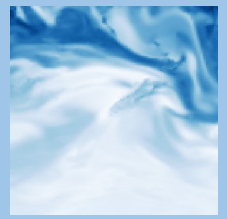
Climate Science

statistical downscaling

downscaling/upscaling

physical quantities





Motivation

High-resolution climate data - useful, but hard to obtain

Useful

Motivate action to combat climate change

Inform climate adaption locally

Impact on agriculture, transportation etc.

Hard to obtain

Computationally intensive

Long runtimes

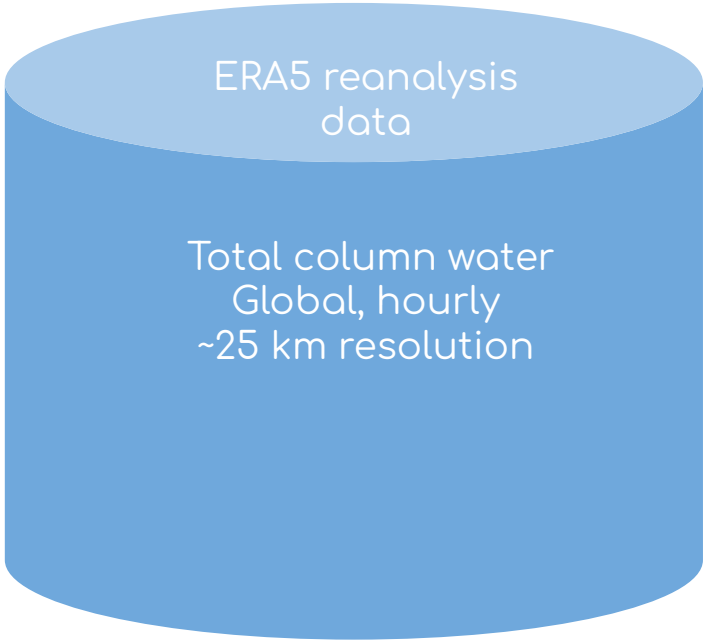
High energy consumption

Observation not available in some areas

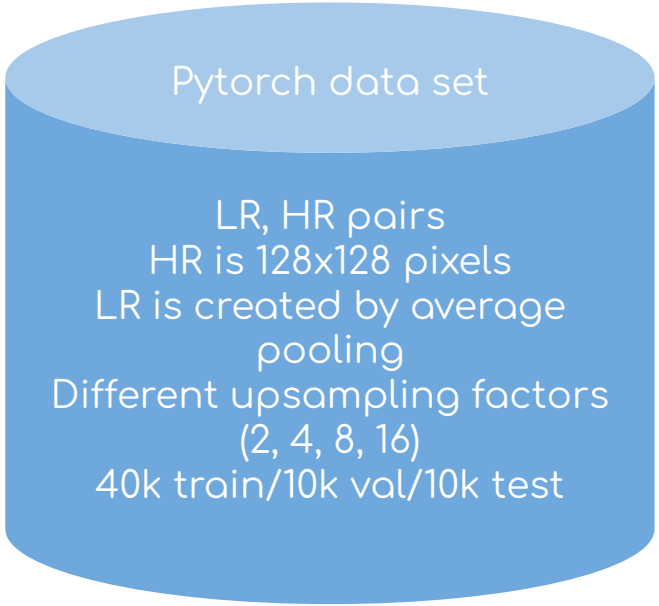
Methods

Data

Underlying climate data



ML ready data set

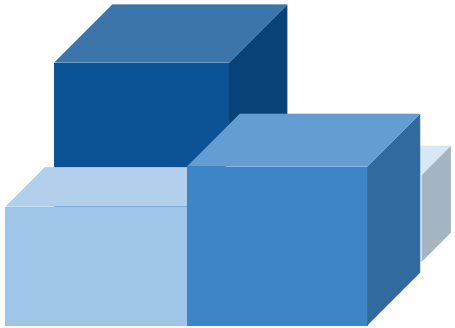


Physics constraints

Predicted quantity is water mass

Want to enforce conservation of mass between low-res input and super-res prediction

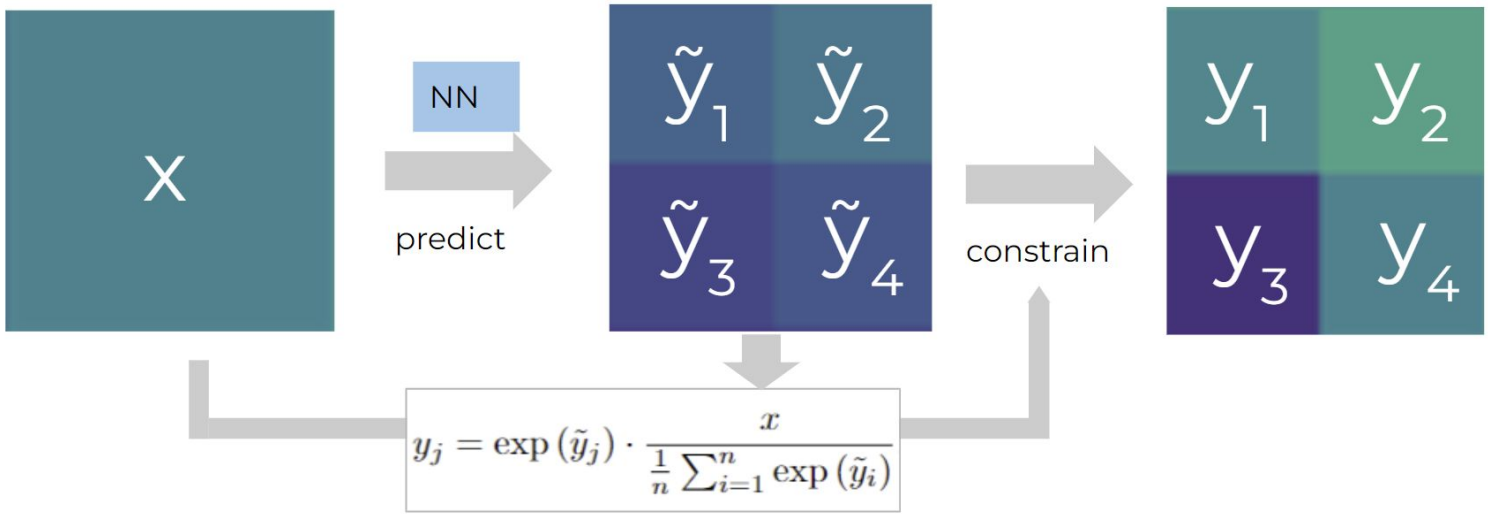
Low-res water mass



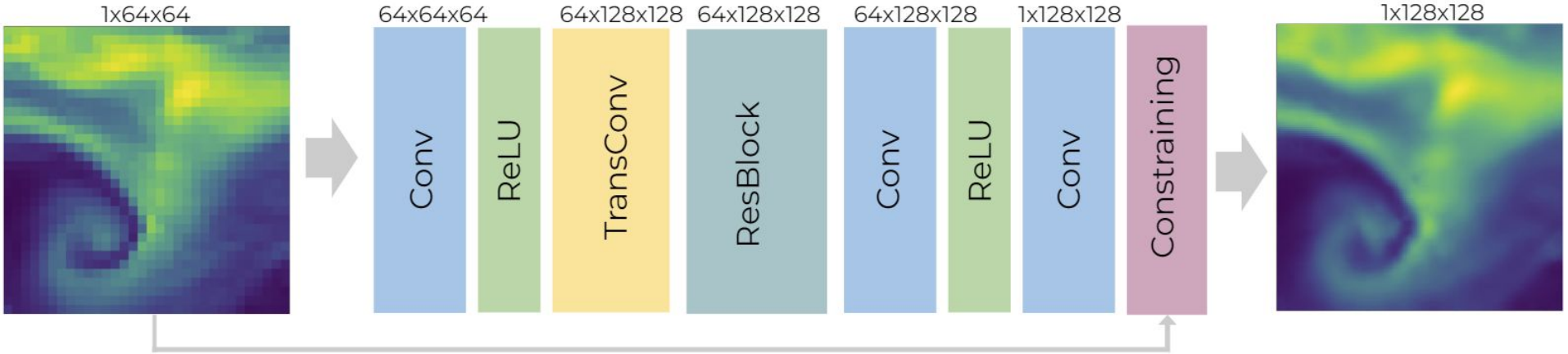
Super-res water mass

Enforcing constraints - Softmax Constraints Layer (SMCL)

SMCL guarantees conservation of mass and positivity



Enforcing constraints - architecture



Results

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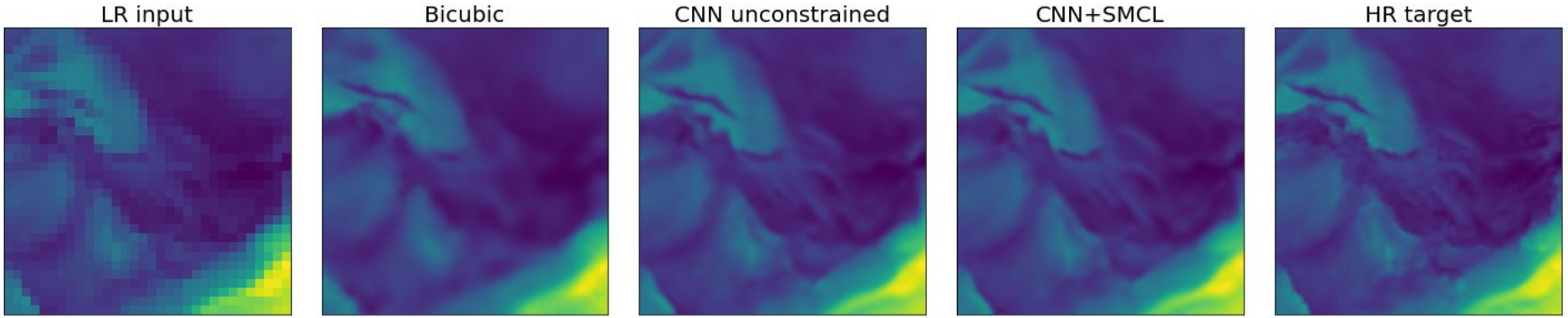
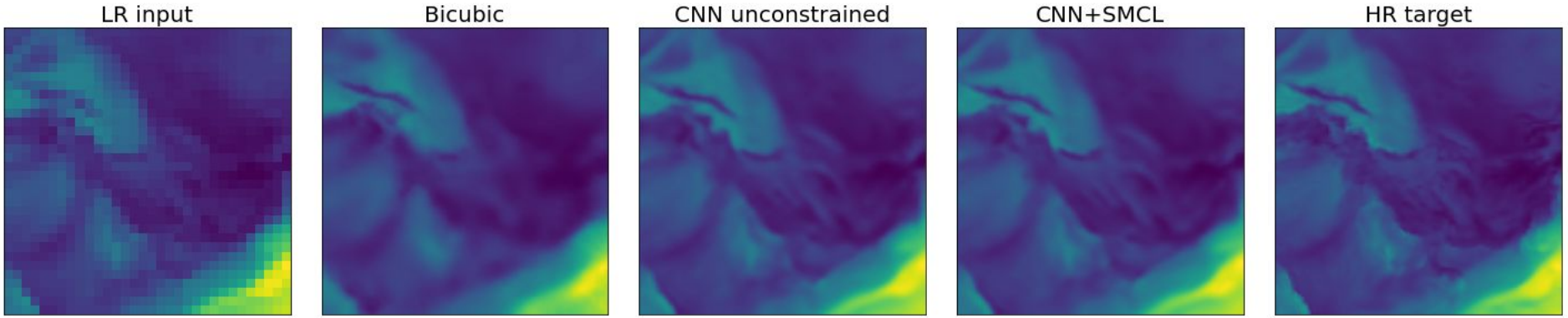


Results- 4 times downscaling



PSNR	44.3	47.5	47.9	

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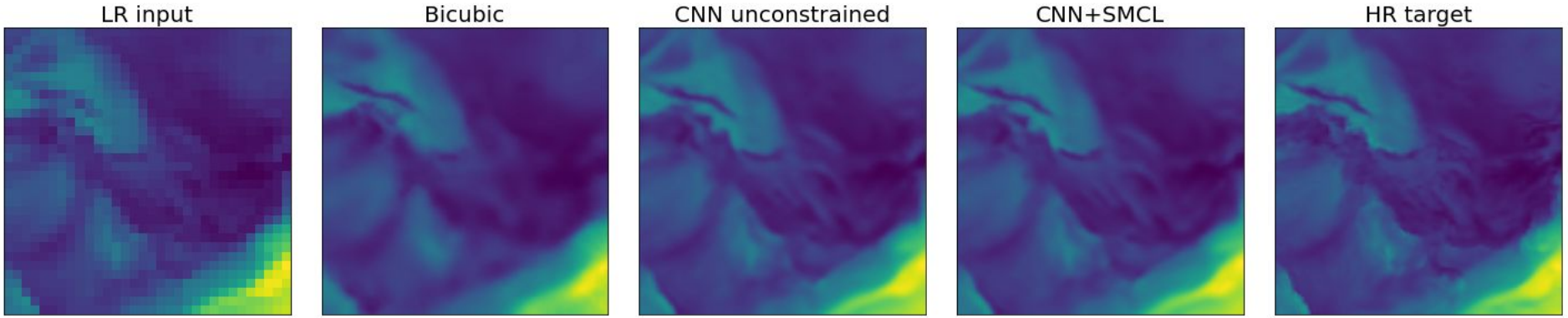

PSNR	44.3	47.5	47.9

$$PSNR = 20 \log_{10} \left(\frac{MAX_f}{\sqrt{MSE}} \right)$$

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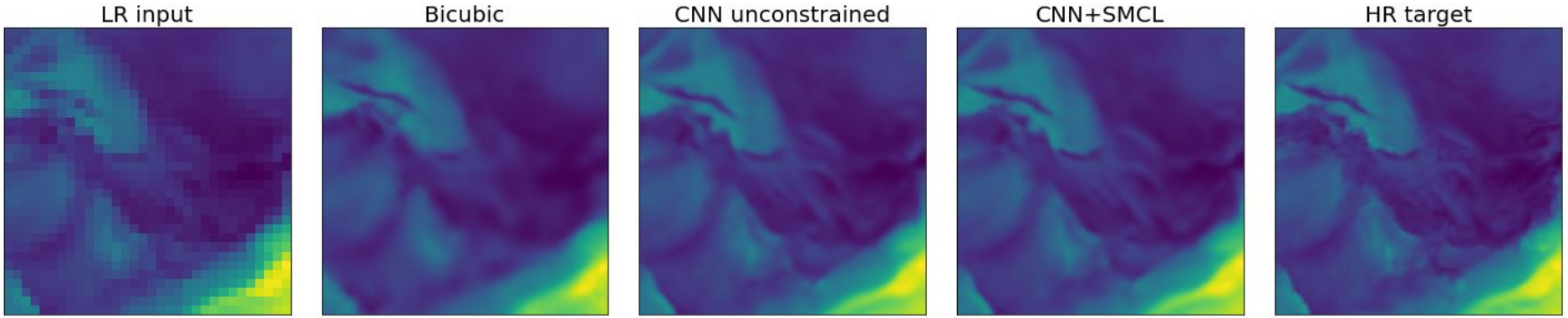

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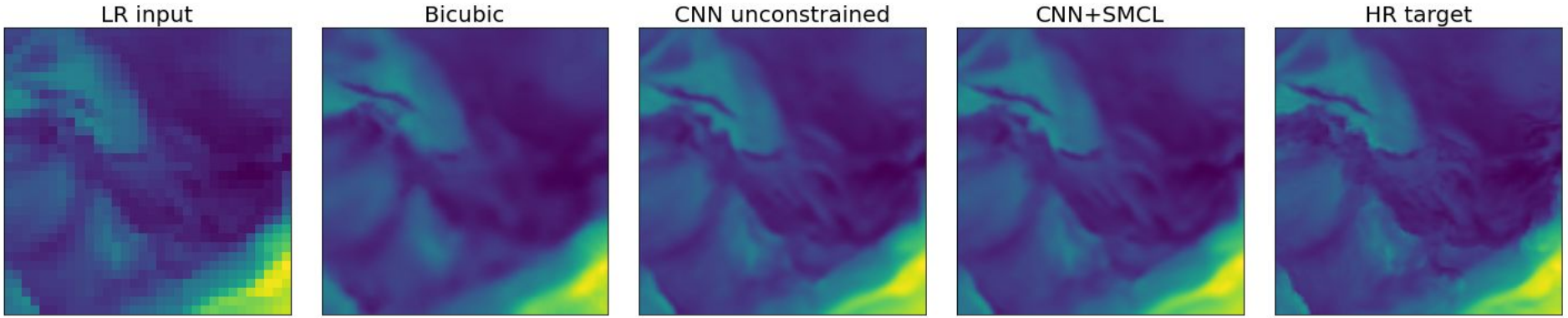

PSNR	44.3	47.5	47.9
Average mass conservation violation	0.17	0.031	0.0000011

Summary

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Applying our Softmax Constraints Layer to deep learning downscaling architectures

enforces physical laws in neural networks

increases predictive accuracy for downscaling

Thanks for your attention!