Data-driven multiscale modeling of subgrid parameterizations in climate models

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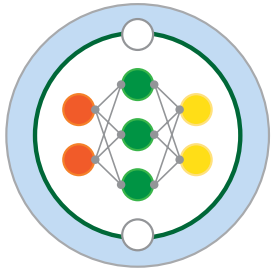
https://m2lines.github.io



Introduction

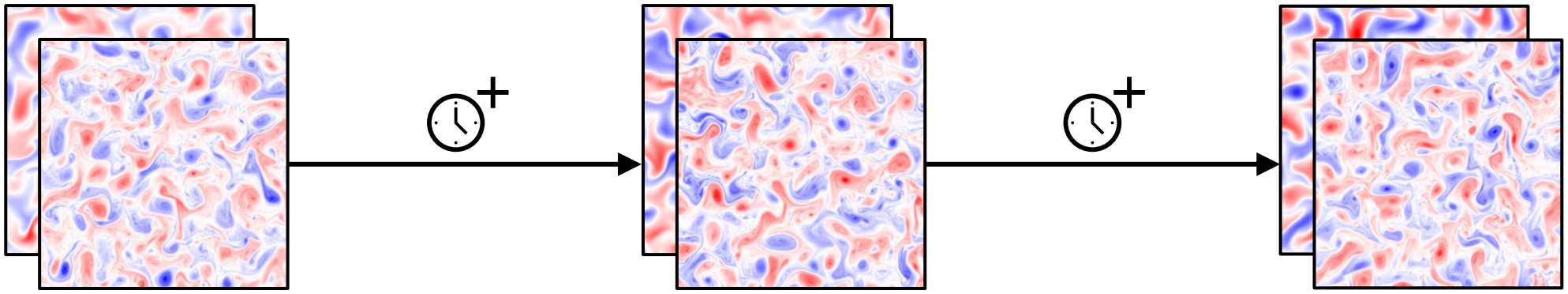
- Climate models help project climate change impacts
- Coarsened resolution impacts model accuracy
- Closure models are added to reflect missing processes

- Active area of research
- Many approaches have been tested
  - Including deep learning methods
- We test an approach decomposing the task across scales

Two-Layer Quasi-Geostrophic Model

- Testbed model used in our experiments
- Based on PyQG (https://github.com/pyqg/pyqg)
  - Ported to the JAX framework

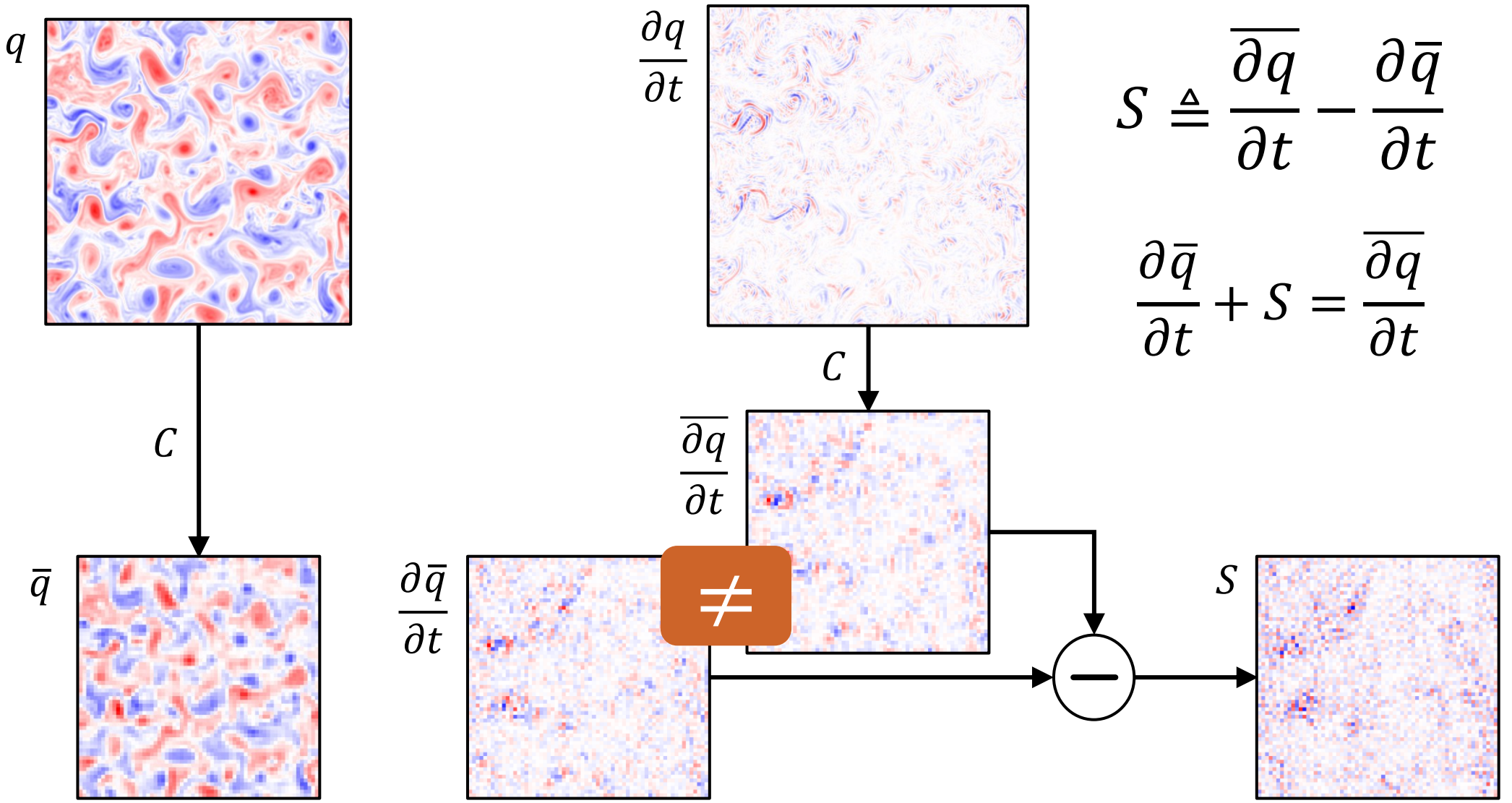
- Tracks the evolution of potential vorticity, q
  - Two layers, periodic boundary conditions



Subgrid Parameterizations

True Resolution

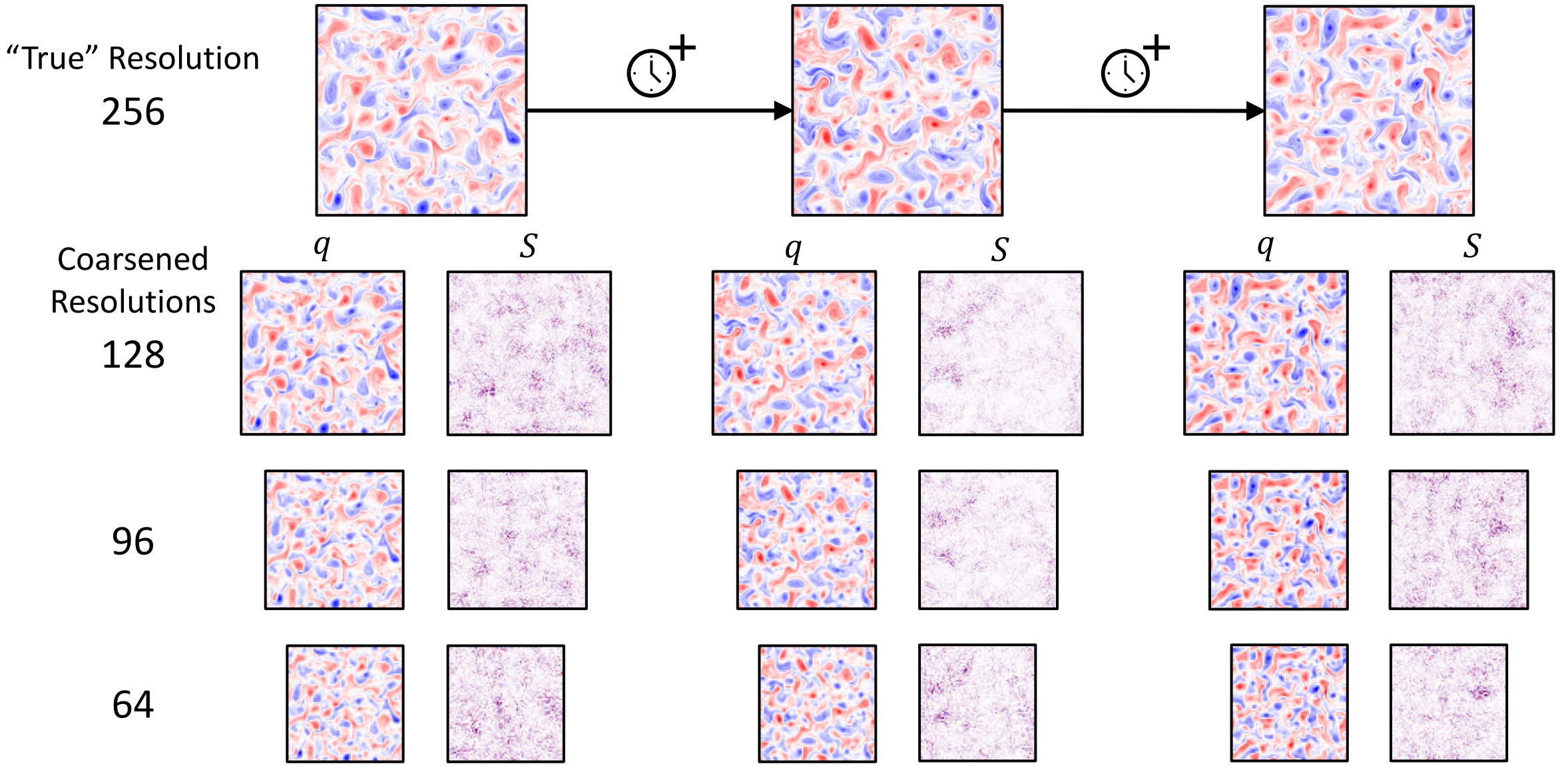
Coarsened Resolution



$$S \triangleq \frac{\overline{\partial q}}{\partial t} - \frac{\partial \bar{q}}{\partial t}$$

$$\frac{\partial \bar{q}}{\partial t} + S = \frac{\overline{\partial q}}{\partial t}$$

Multiscale Subgrid Parameterizations



Subgrid Forcing Prediction

- We generate 100 trajectories for training
- Each with 10,800 steps

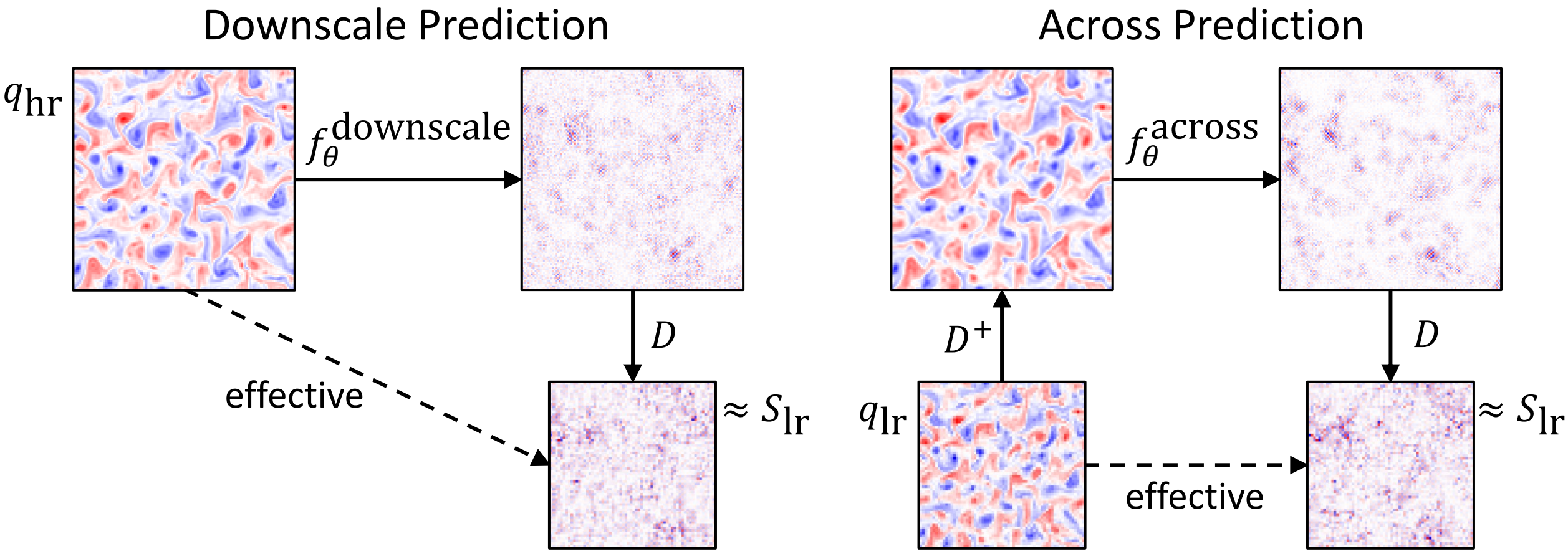
- We use two network architectures:
  - Small: Kernels of size 3x3 and 5x5
  - Large: Kernels of size 5x5 and 9x9

Experiments

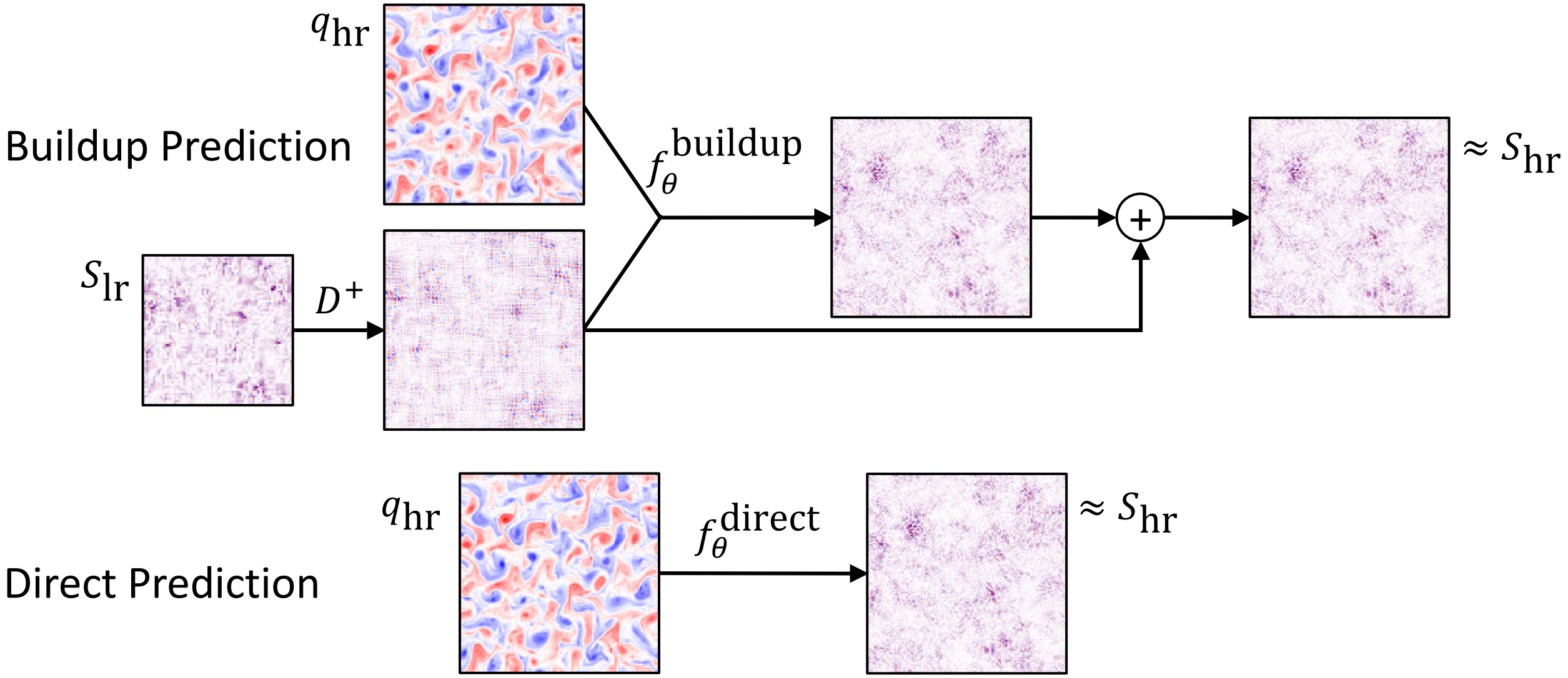
Three types of experiments:

1. Downscale prediction
   - Predict a coarse version of the target output
2. Upscale prediction
   - Upscale the coarse prediction to the required resolution
3. Combined prediction
   - Use both networks to make a full prediction

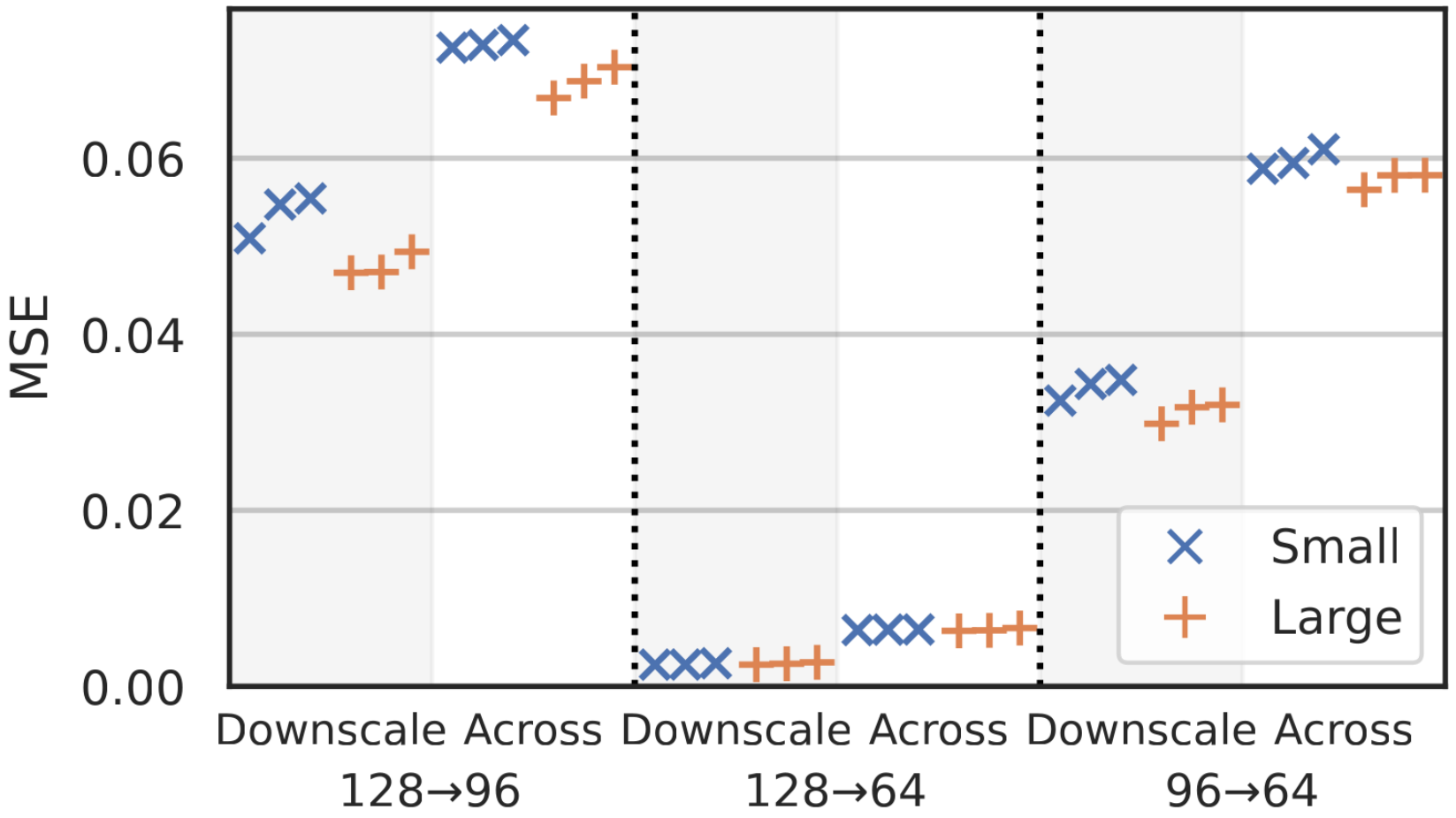
Downward Prediction



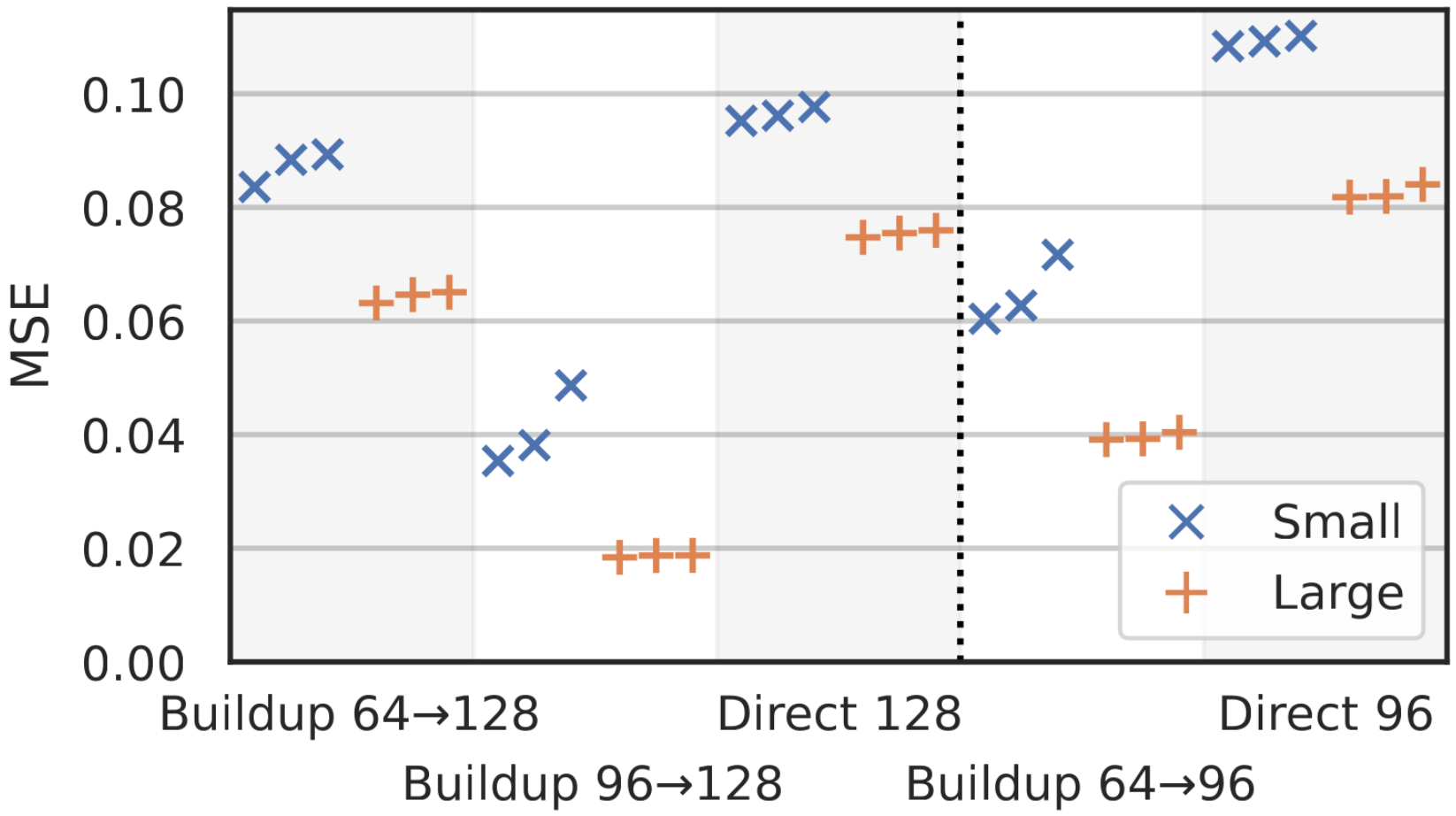
Upward Prediction



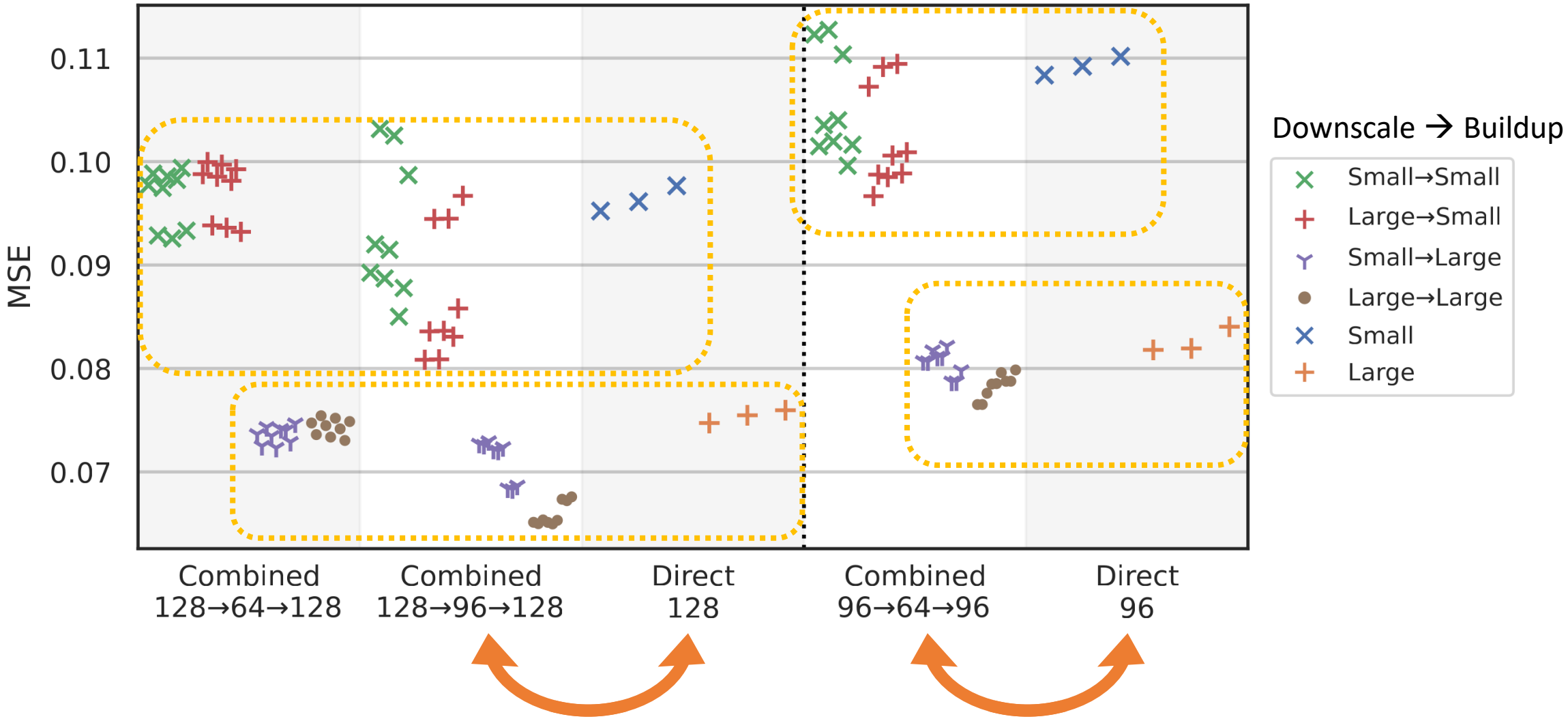
Downscaling Experiments



Upscaling Experiments



Combined Prediction



Future Work

First steps in an ongoing project

- Online evaluation
- Test on additional climate tasks
- Investigate regularization benefits
- Improvements to model architecture

Resources

Extended arXiv Preprint

https://arxiv.org/abs/2303.17496

JAX Quasi-Geostrophic Model

https://github.com/karlotness/pyqg-jax