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Machine Learning Emulation of a Quasi Two-Moment Microphysical Scheme with Diagnosed Particle Sizes

AMERICAN METEOROLOGICAL SOCIETY
104TH ANNUAL MEETING
28 JANUARY-1 FEBRUARY 2024
BALTIMORE, MD & ONLINE

Introduction

- The distribution of precipitation particle size significantly influences the dynamics of storms through processes such as evaporation, sedimentation, coalescence, etc..
- Microphysical schemes with detailed representations of Particle Size Distributions (PSD) exist but are computationally intensive and difficult to tune.
- While double moment microphysical schemes are computationally efficient and easier to tune, they account only approximately for PSD processes.
- Joint distributions of various PSD parameters appear distorted when compared to those derived from ground observations.
- Here, we investigate the impact of adjusting the 0th moment of the Morrison two-moment scheme on the predicted precipitation.

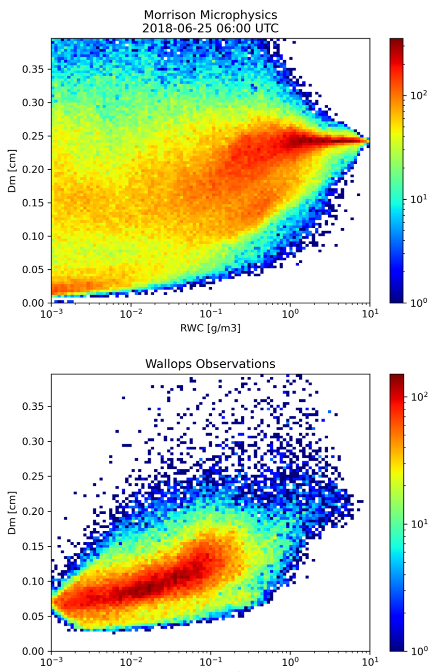

Fig. 1.Joint distribution of the rain-water content and the associated Dm derived from the Morrison scheme and video disdrometer observations.

Methodology

- Run WRF with multiple two-moment schemes and produce microphysics data.
- Develop ML model to predict mass-equivalent diameter, D_m, from pressure, temperature, water vapor , and hydrometer mixing ratios.
- The ML model is based on a sequence of multichannel 1D convolutional layers.
- Investigate the ML model performance.
- Devise a strategy to incorporate D_m diagnostics into the Morrison scheme.

D_m Diagnostic Results

- The ConvNet model appears capable of accurately diagnosing D_m from the third moment of hydrometeor PSDs and environmental variables.
- However, accurate data is required to improve a two-moment scheme through diagnostic adjustments of the 0^{th} moment.
- Simulations using more complex microphysical scheme (e.g. three moment or SBM) may be used in principle, but even such simulations may be biased and unrealistic.
- Simpler adjustments based on direct PSD observations may provide a short-term solution.

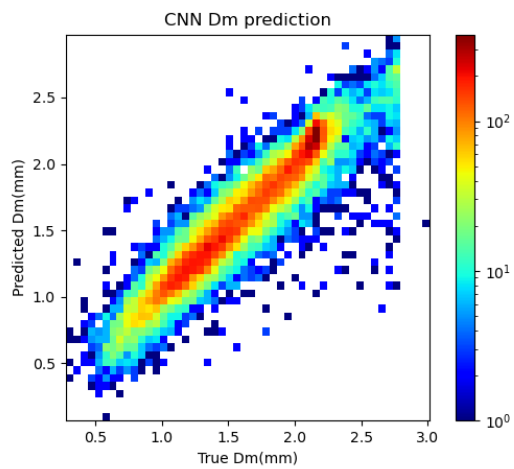

Fig. 2. D_m diagnosed by ConvNet as a function of the true Dm.

Adjustment Results

- While the differences between the patterns of surface precipitation produced by the nominal and adjusted Morrison schemes are subtle, intensity differences are significant.
- The adjusted scheme produces smaller areas of light precipitation, but more intense precipitation overall .
- Adjustments in the ice phase are expected to be more consequential.

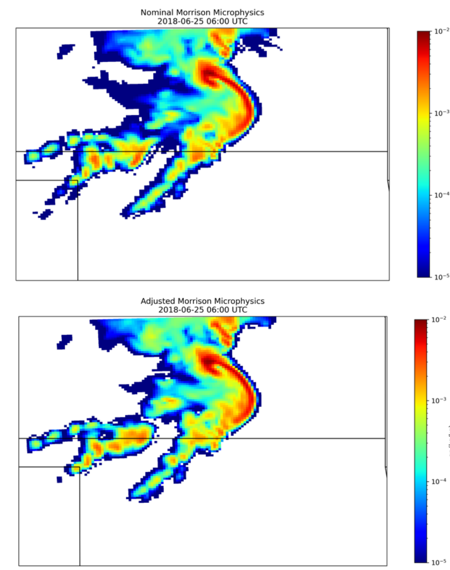

Fig. 3. Precipitation predicted using the nominal and the adjusted Morrison schemes.

Summary and future work

- ML corrections based on computationally light physical schemes are more practical than full emulators (at least in short-term).
- The ConvNet diagnostic model appears to be accurate in the simulation experiment but, to be effective in practice, more realistic training data are needed.
- We are exploring strategies to curb the possibility of runaway growths in random errors and/or conditional biases of the corrections to ensure stability and accuracy.