Development of neural network ensemble stochastic convection parameterizations for climate models using CRM simulated data

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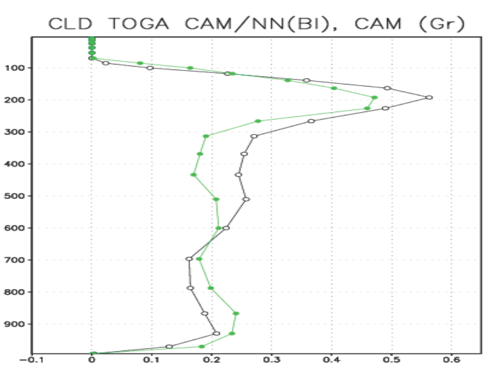
A novel approach based on the neural network (NN) technique has been formulated and used for development of NN ensemble stochastic convection parameterizations for climate and NWP models. This fast NN convection parameterization is built based on direct learning cloud physics from Cloud Resolving Model SAM (System for Atmospheric Modeling, Khairoutdinov and Randall, 2003) simulated data. SAM simulations have been initialized with and forced by 120-day long TOGA-COARE data. SAM data simulated over the TOGA-COARE location have been averaged to produce hourly and horizontally, 256 km x 256 km, means. The data was projected onto a GCM space of atmospheric states to implicitly define a stochastic convection parameterization. That is only a subset of relevant SAM variables available in a climate model (NCAR CAM) is selected for creating an NN training data set.

An ensemble of NNs have been trained and their accuracy is estimated vs. SAM simulated data. This NN ensemble represents the stochastic convection parameterization. The inherent uncertainty of the stochastic convection parameterization is indicated and estimated.

Validation of the NN stochastic convection parameterization in NCAR CAM has been done in a diagnostic mode (CAM/NN). Actually, CAM inputs have been used, at every time step and grid point for calculations of the NN convection parameterization to produce its outputs as a diagnostic product. Parallel decadal CAM and CAM/NN simulations have been produced for 1990-2001 for winters (NDJF) excluding the TOGA-COARE 1992-93 winter. The CAM/NN run includes bias corrections or model calibration. SAM-CAM bias corrections are consistently applied to NN inputs and outputs to account for differences between SAM and CAM or their different "virtual realities". SAM-CAM bias corrections are calculated for the TOGA-COARE point (-2 S, 155 E) and time averaged for the TOGA-COARE winter. The point bias is applied at every time step and grid point throughout the decadal CAM/NN diagnostic run. The CAM/NN and CAM runs are compared for consistency, and with the NCEP reanalysis



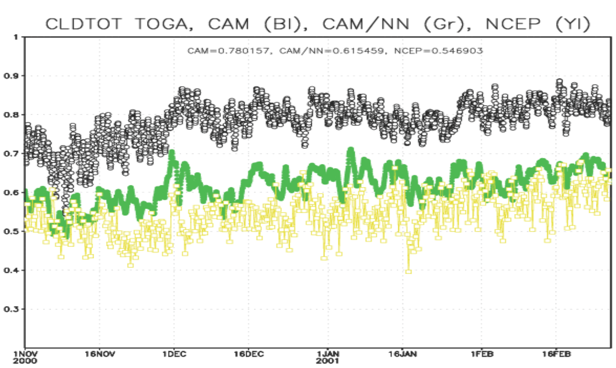


Fig. 1 (left) Vertical profiles of decadal mean CLD, in fractions, for CAM/NN and CAM

Fig. 2 (right) Time series of decadal mean total cloudiness (in fractions) for the TOGA-COARE location for the CAM run (black) and CAM/NN (green) runs, and for the NCEP reanalysis (yellow).

The decadal mean CLD profiles for CAM/NN and CAM (Fig. 1) are consistent and close to each other including the maximum at 200 hPa. The time series of the decadal mean total CLD (Fig. 2) for the CAM run show measurably higher magnitudes, with the mean of 0.78, compared to those of the time series for the CAM/NN run, with the mean of 0.61. The time series of the NCEP reanalysis show lower magnitudes, with the mean of 0.54, which are significantly closer to those of the time series for CAM/NN.

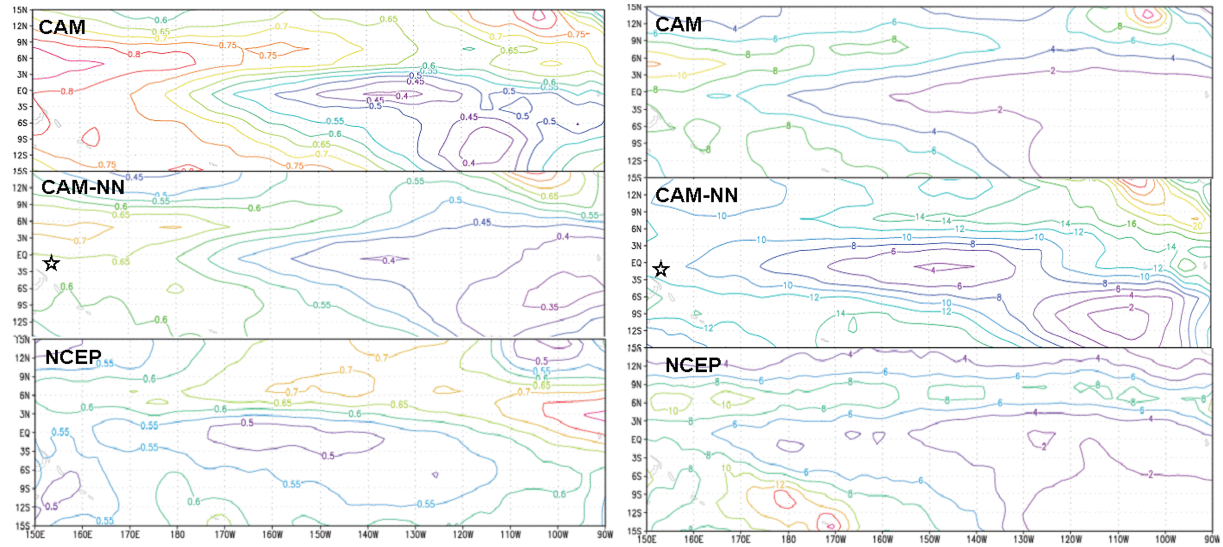


Fig. 3 Decadal mean winter (NDJF) distributions for the Tropical Pacific region for CLD (left panels), in fractions, and precipitation (right panels), in mm/day, for: NCEP reanalysis (the bottom panels), the CAM/NN with the SAM-CAM bias corrections run (the middle panels), and the CAM run (the upper panels). The TOGA-CORE location, for which the NN convection parameterization and bias correction have been calculated for the TOGA-COARE winter only, is shown by a star in the middle panels.

The patterns of both CLD and precipitation for the CAM/NN run are generally consistent with those of the CAM run, and with those of the NCEP reanalysis. The CLD magnitudes for the CAM/NN run are measurably closer to those of the NCEP reanalysis than those of the CAM run. Compared the NCEP reanalysis, the PREC magnitudes for the CAM/NN run are closer to those of the CAM run for 15º S to around the Equator, but overestimated for the area north of 6º N.

The CLD decadal time series for the TOGA-COARE location and the CLD distribution for the Tropical Pacific region are consistent in the sense that for both the CAM run shows measurably higher magnitudes compared to those of the CAM/NN run, the later being much closer to those of the NCEP reanalysis. These results obtained for the decadal CAM/NN simulation seem to be positive and encouraging.

Conclusions: (1) A novel NN approach has been formulated and used for development of NN ensemble stochastic convection parameterizations for climate models. **(**2) Developed NN ensemble stochastic convection parameterizations have been tested in parallel decadal CAM/NN and CAM runs. The obtained results are positive and encouraging.

Future plans: Developing NN ensemble stochastic convection parameterizations using SAM simulations driven by CAM forcing for longer periods, different geographic locations, and diverse weather conditions. It will allow us to develop a NN ensemble stochastic convection parameterization that can be used globally.

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References

Khairoutdinov, M., and D. Randall, 2003: Cloud resolving modeling of the ARM summer 1997 IOP: Model formulation, results, uncertainties, and sensitivities. *J. Atmos. Sci.*, **60,** 607–625.

Krasnopolsky, V., M. Fox-Rabinovitz, A. Belochitski P. Blossey, and Y. Kogan, 2010: Development of neural network convection parameterizations for climate models using Cloud Resolving Model simulations, NCEP Tech. Note, in press

Krasnopolsky, V., M. Fox-Rabinovitz, P. Rasch, A. Belochitski, P. Blossey, and Y. Kogan, 2010: Neural network convection parameterizations for climate models based on statistical learning from Cloud Resolving Model simulations, paper in preparation.