Sensitivity of observable output of modeled microphysics to stochastically perturbed parameters

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Background

Stochastically Perturbed Parameteization (SPP) schemes are used in weather and Earth system ensemble modeling to represent variability of unresolved sub-grid scale processes and epistemic uncertainty about the parametrizations

The uncertainty is modeled by stochastic perturbations to physical parameters within a parameterization using AR1 process controlled by choice of spatial and temporal decorelation scales and statistical parameter distributions

Positive impacts were shown for ensemble prediction from daily to climate time scales, recommending further development of physically-based multi-parameer stochastic perturbation schemes (Olinaho et al 2017)[1]

Approach

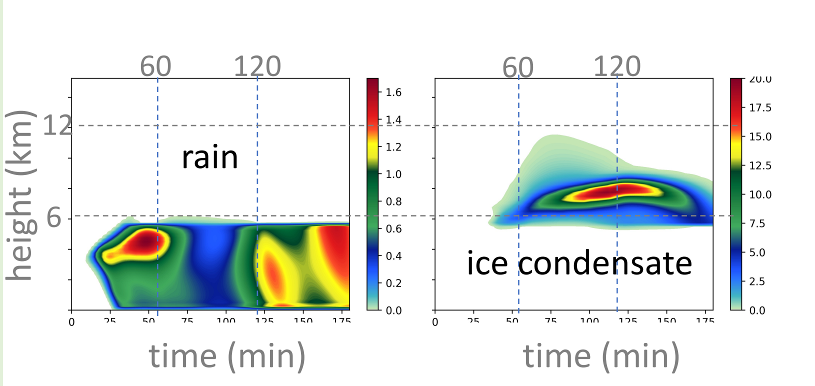
Further development should take advantage of abundance of remote sensing observations with high information content about state of microphysics

As a first step we investigated sensitivity of satellite observable output of cloud and precipitation microphysics parameterization to SPP scheme using lagrangian 1D column microphysics model forced with prescribed time-varying profiles of temperature, humidity and vertical velocity.

This modeling framework allows for study of the effect of changes in model physics parameters on the model output in isolation from any feedback to the cloud-scale dynamics

Modeling and data

Ensemble simulations of idealized squall-line convection were performed with 1D column NASA-GCE single moment microphysics model



Sensitivity to SPP was investigated for parameters to which 1D model is most sensitive based on prior study where parameter uncertainty was characterized by MCMC multivariate nonlinear inversions using simulated satellite remote sensing observations (Posselt and Vukicevic 2010)[2]

Data from this prior study were used to estimate variance and covariance for parameter perturbations in SPP

Olinaho et al, 2017 : Towards process-level representation of model uncertainties: stochastically perturbed parametrizations in the ECMWF ensemble.

Posselt, D. and T. Vukicevic, 2010: Robust characterization of model physics uncertainty for simulations of deep moist convection. Mon. Wea. Rev..,138.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 101003352

Sensitivity experiments

Each includes ensemble of 100 model simulations with different stochastic sequences of parameter variations

Perturbed physical parameters :
- Fall speed params for snow and graupel
- Particle densities for snow and graupel
- Intercept parameters for the rain, snow, and graupel particle size distribution
- Autoconversion threshold for conversion from cloud to rain

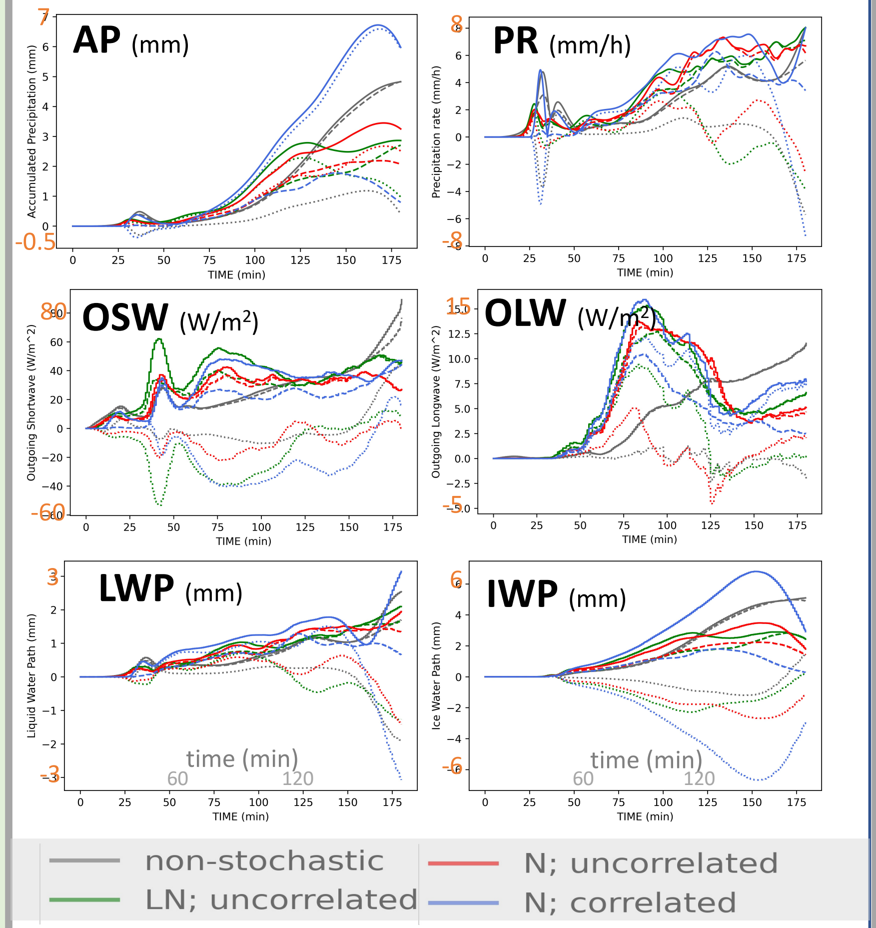
Sensitivity to
- Parameter distribution
  Log-normal and Normal
- Second moment statistics
  uncorrelated and correlated
- Choice of parameters
- Decorrelation time of AR1 process
  1, 3 and 12 h
- stochastic vs non-stochastic

Diagnostics in observation space

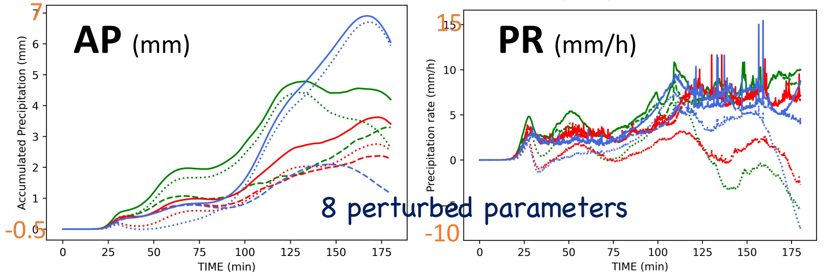
AP, PR, LWP, IWP, OLW, OSW
- Ensemble rmse and bias relative to unperturbed model (best estimate params)
- Ensemble spread
- Extremes

Rmse (solid) and bias (dotted) relative to unperturbed model and ensemble spread (dashed)

7 perturbed parameters



Impact of adding rain psd intercept param to SPP



Conclusions

- For all configurations SPP induces significant time varying bias in the microphysics model ensemble solution with amplitude dependent on storm phase

- Strongest sensitivity during and after transition from convective to stratiform phase reflected in large changes to radiative fluxes

- Large sensitivity to correlated perturbations and estimates of covariance

- SPP with LN distribution causes higher extremes but produces similar ensemble mean statistics to experiments with Normal distribution

- Small sensitivity to decorrelation time

- Selection of SPP parameters has significant and state-dependent impact on model output

- Results point to need for objective estimates of multi-parameter distributions consistent with storm morphology

- Inversions using satellite observations may be considered for this purpose