Aerosol Impacts on Deep Convective Clouds: Microphysical Effects Determine Cloud Macrophysical Response

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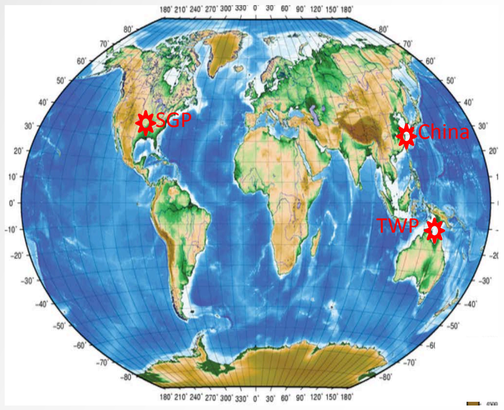
INTRODUCTION

- Deep convective clouds (DCCs) play a crucial role in the general circulation, energy budget, and hydrological cycle of our climate system.
- Aerosols reportedly invigorated and suppressed DCCs from modeling studies, but quantifying their impacts on entire convection life cycle was ignored.
- By conducting multiple month-long cloud-resolving simulations with spectral-bin cloud microphysics, this study provides a first comprehensive look at how aerosols affect entire cloud lifecycle, and finds a new mechanism for the observed larger and taller clouds in the polluted environment, even when invigoration is absent.

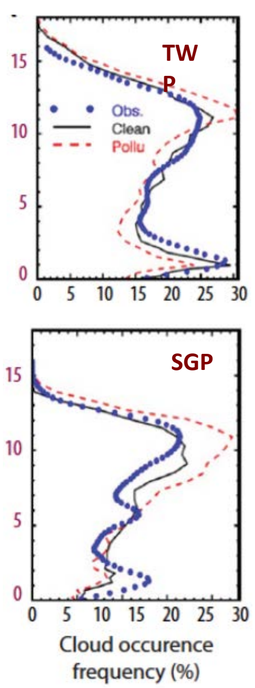
EXPERIENT DESIGN

- WRF with Spectral-bin Microphysics (SBM; Khain et al., 2004, 2009; Fan et al., 2012).
- NCEP FNL data are used to provide initial and boundary conditions.
- Two domains two-way nested runs over three regions with horizontal resolution of ~2 km for the inner domain. 1-month simulation time.
- For each region, simulations were conducted for clean and polluted conditions, with typical CCN concentrations of 280 and 6 x 280 cm^{-3}, respectively.

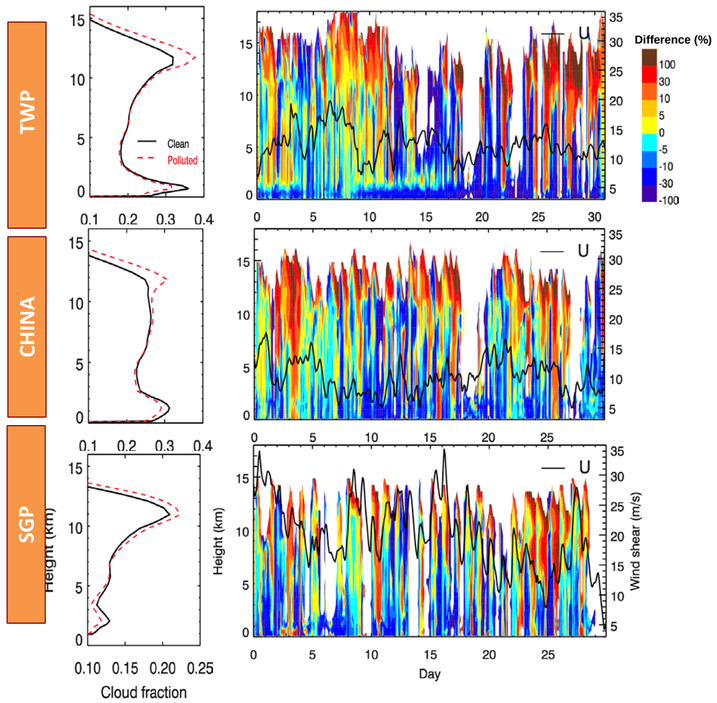


RESULTS

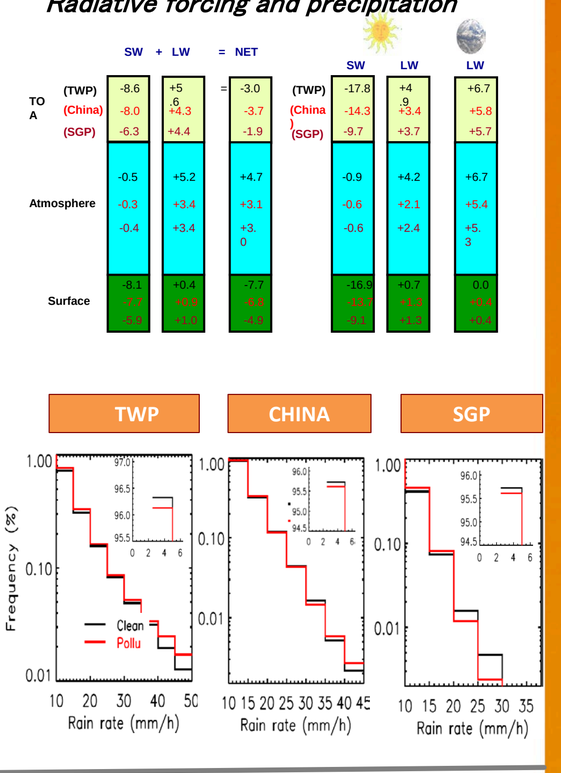
Validation of simulations



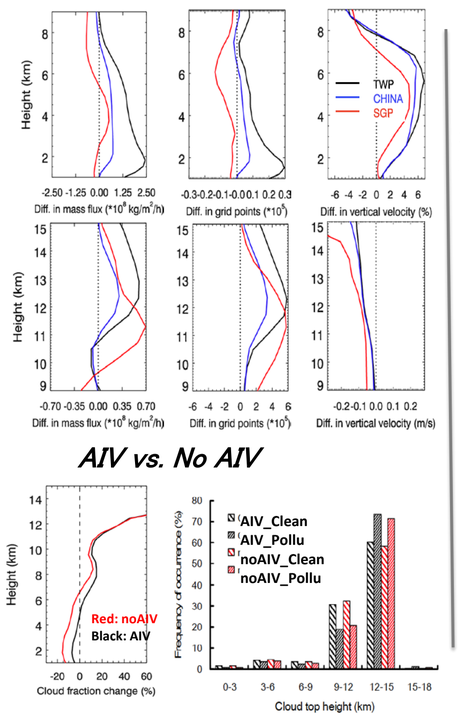
Enlarged cloud coverage, and increased cloud top heights (CTH)



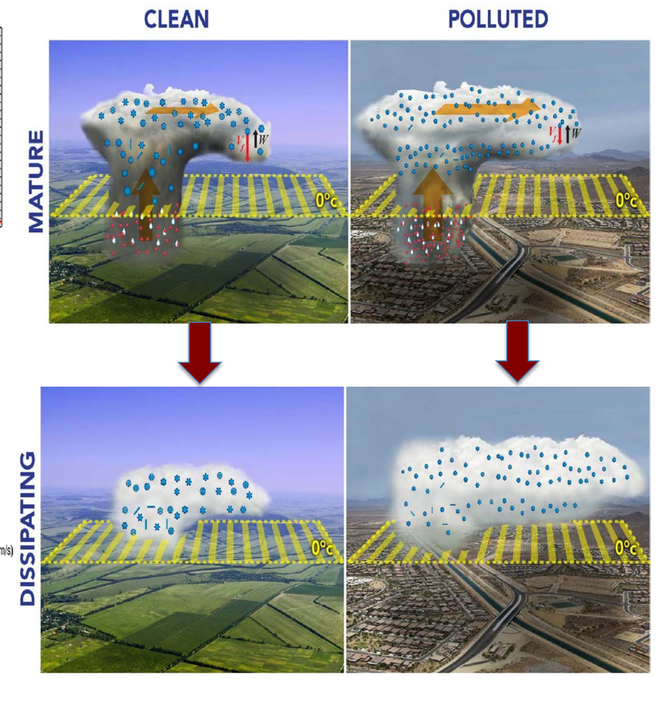
Radiative forcing and precipitation



The determining factor: dynamical or microphysical effects?



AIV vs. No AIV



CONCLUSIONS

- **Aerosols enlarge cloud cover, increase CTH, and cloud thickness in deep convective clouds, consistent with results of observational studies (not shown).**
- **Microphysical aerosol effect is the fundamental determinant by inducing larger amount of smaller but longer-lasting ice particles in the stratiform/anvils of DCCs.**
- **The invigoration effect by increasing aerosols is adjusted by the large-scale dynamics and also buffered partially by the feedback of radiative forcing, leaving the microphysical effect to dominate the changes on cloud properties.**

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