# CLOUD-SYSTEM RESOLVING MODEL SIMULATIONS OF AEROSOL INDIRECT EFFECTS FOR TWP-ICE: SENSITIVITY TO REPRESENTATION OF MICROPHYSICS AND MODEL RESOLUTION

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## Overview

Previous studies have hypothesized that aerosols can have a large impact on the character of deep convection and its associated precipitation (e.g., Levin and Cotton 2009).

The effects of aerosols on clouds and precipitation in cloud system-resolving model (CSRM) simulations of tropical deep convection is uncertain (e.g., Tao et al. 2007), but systematic investigation of sensitivity of aerosol indirect effects (AIE) to model components such as microphysics and horizontal grid spacing has generally been lacking. This uncertainty is especially important in light of recent efforts to quantify AIE using CSRMs embedded in the global multiscale modeling framwork (MMF).

The goals of this study are to:

• Evaluate a cloud-system resolving model by comparing with observations and microphysical retrievals,

• Test sensitivity of AIE to representation of microphysics and model resolution.

## Description of the Microphysics Scheme

2-moment bulk liquid+ice scheme (prediction of mass mixing ratio and number concentration)

• Liquid scheme: Morrison and Grabowski (2007, 2008a)

• Ice scheme: Morrison and Grabowski (2008)

In the new ice scheme, different ice types are not separated into different species (e.g., cloud ice, snow, graupel) a priori as in traditional schemes. Instead, ice growth via riming and vapor diffusion follows from the conceptual model of Heymsfield (1982), based on separate prediction of rime and vapor deposition mass mixing ratios.

## Cloud-Aerosol Coupling

• Cloud droplet activation from a multimodal lognormal aerosol size distribution

• Ice nucleation from heterogeneous immersion freezing of cloud droplets (Bigg 1953), deposition/condensation-freezing (Meyers et al. 1992), and homogeneous freezing. Ice nucleation is not explicitly coupled to aerosol.

• Wet scavenging by precipitation below cloud base is neglected. Background aerosol is assumed to be constant in time.

## Application to TWP-ICE: Baseline Results

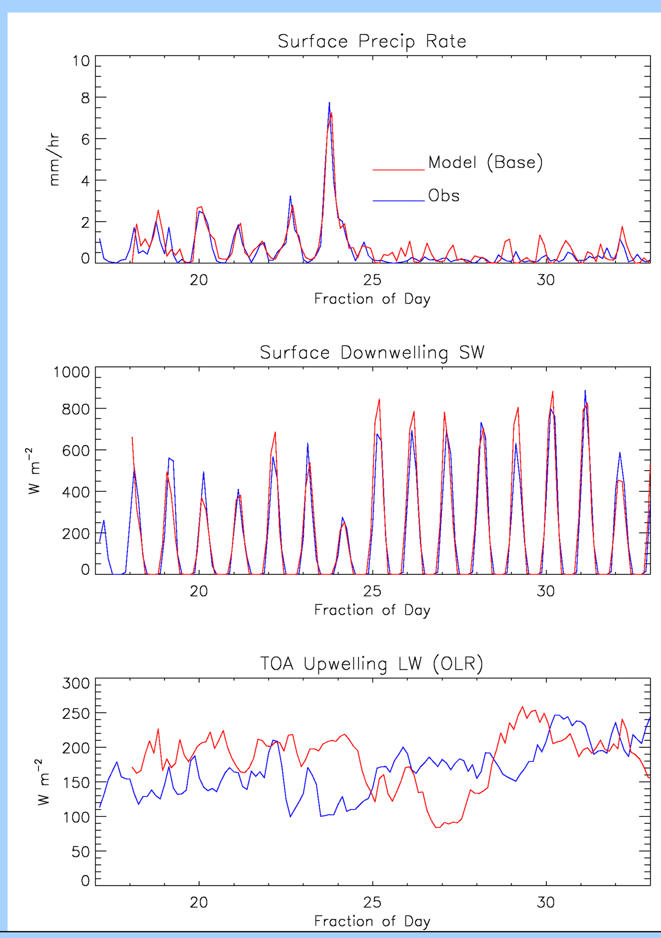
Simulations of the Tropical Warm Pool – International Cloud Experiment (TWP-ICE) have been conducted with a version of the anelastic Eulerian-Lagrangian (EULAG) cloud model (Grabowski and Smolarkiewicz 1999)

Setup same as TWP-ICE cloud model intercomparison (Fridlind et al. 2008):

•Simulation period: Jan 17 to Feb 3, 2006, 10 mb V2 ARM forcing/initial dataset
•2D, 97 vertical levels with stretched vertical coordinate, 201 x 25 km domain, 1 km grid spacing (baseline)
•Monin-Obukhov surface similarity to calculate surface fluxes
•CCSM2 longwave and shortwave radiation
•Three mode aerosol from observations following TWP-ICE model intercomparison

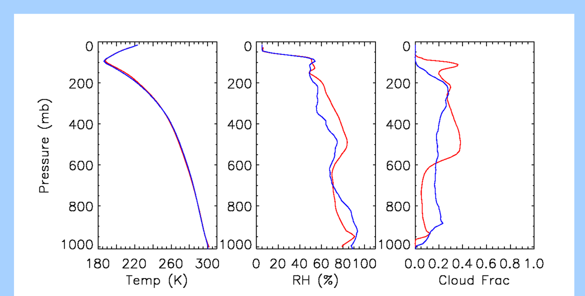
**Baseline model produces overall reasonable results for the case.**

*Modeled and observed* timeseries of domain-mean surface rain rate, TOA upwelling LW flux, and surface downwelling SW flux.*




*From V2 10 mb TWP-CE forcing files provided by S. Xie

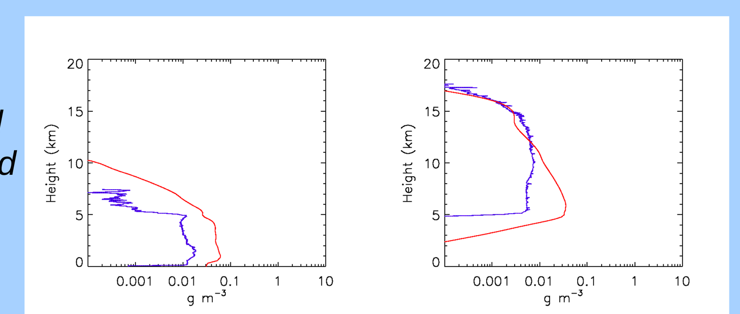
*Modeled and observed* time- and domain-mean temperature, water vapor, and cloud fraction# profiles.*




#Modeled cloud fraction defined using threshold cloud water/ice mixing ratio of 0.001 g kg$^{-1}$.

Model
Observations

*Modeled and retrieved time- and domain-mean liquid water content and ice water content*




## Sensitivity Tests

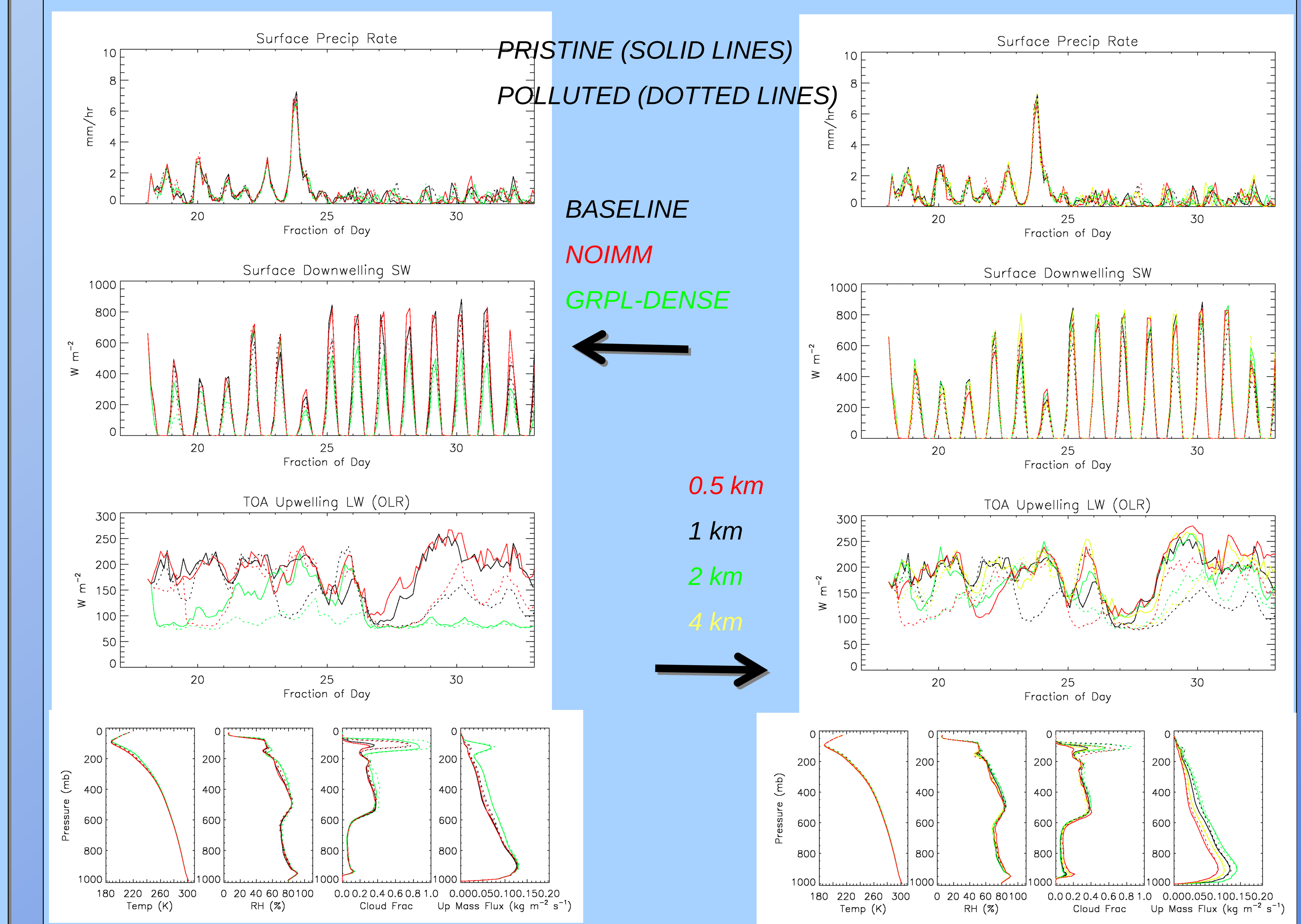
Several sets of model simulations are run with baseline, relatively pristine aerosol observed during TWP-ICE (PRISTINE), or relatively polluted aerosol (POLLUTED) as observed in the region during the Nov. 2005 Aerosol and Chemical Transport in Tropical Convection experiment (ACTIVE). Low-level aerosol concentrations ~ 200 cm$^{-3}$ for PRISTINE and 2000 cm$^{-3}$ for POLLUTED.

**Microphysical sensitivity tests**
•No immersion freezing of cloud droplets (NOIMM)
•Baseline graupel density from Locatelli and Hobbs (1974) replaced with lower-density graupel from Heymsfield and Kajikawa (1987) (GRPL-DENSE)

**Horizontal grid spacing sensitivity tests**
•0.5, 1 (baseline), 2, 4 km

## Sensitivity Test Results

*Modeled timeseries of domain-mean surface rain rate, TOA upwelling LW flux, and surface downwelling SW flux.*




*Modeled time- and domain-mean temperature, water vapor, cloud fraction, and updraft mass flux profiles.*

*Modeled time- and domain-mean differences in mean net top-of-atmosphere longwave (LW), shortwave (SW), and total radiative fluxes.*

| RUNS | LW FORCING | SW FORCING | TOTAL |
|---|---|---|---|
| BASELINE | +58.5 | -26.8 | +31.7 |
| NOIMM | +16.9 | -25.6 | -8.8 |
| GRPL-DENSE | +59.6 | -27.1 | +32.5 |
| 0.5 km | +38.7 | -13.9 | +24.8 |
| 2 km | +23.2 | -14.9 | +8.3 |
| 4 km | +41.8 | -19.0 | +22.8 |

## Conclusions

• There is little overall difference in precipitation between PRISTINE and POLLUTED, which is mostly determined by large-scale forcing rather than cloud-scale dynamics and microphysics.

• There are large differences in TOA radiative forcing between PRISTINE and POLLUTED, mostly reflecting the impact of changes in anvil cloud fraction.

• LW aerosol indirect effects tend to dominate SW effects, resulting in net positive forcing. However, magnitude of indirect aerosol effects are highly sensitive to treatment of graupel density, and moderately sensitive to model resolution (for grid spacing between 0.5 and 4 km). Aerosol indirect effects exihbit a nonmonotonic response to changes in horizontal grid spacing.

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