

Introduction

Clouds tremendously affect the surface solar irradiance and its direct and diffuse partitions; accurately forecasting solar radiation in cloudy conditions poses a major challenge. This study employs a new model evaluation framework based on WRF-Solar model to investigate the effects of cloud microphysics and cloud-aerosol interactions on solar irradiance. This work has three objectives:

- To investigate the uncertainty spread of surface solar radiation and its partitions due to different cloud microphysics schemes.
- To explore the aerosol-cloud-radiation interactions.
- To identify the physical causes that lead to model bias for future improvement

Model Evaluation Framework

WRF-Solar testbed suite: Three different configurations based on the state of art Weather Research and Forecasting model specifically designed for simulating and forecasting solar radiation (WRF-Solar).

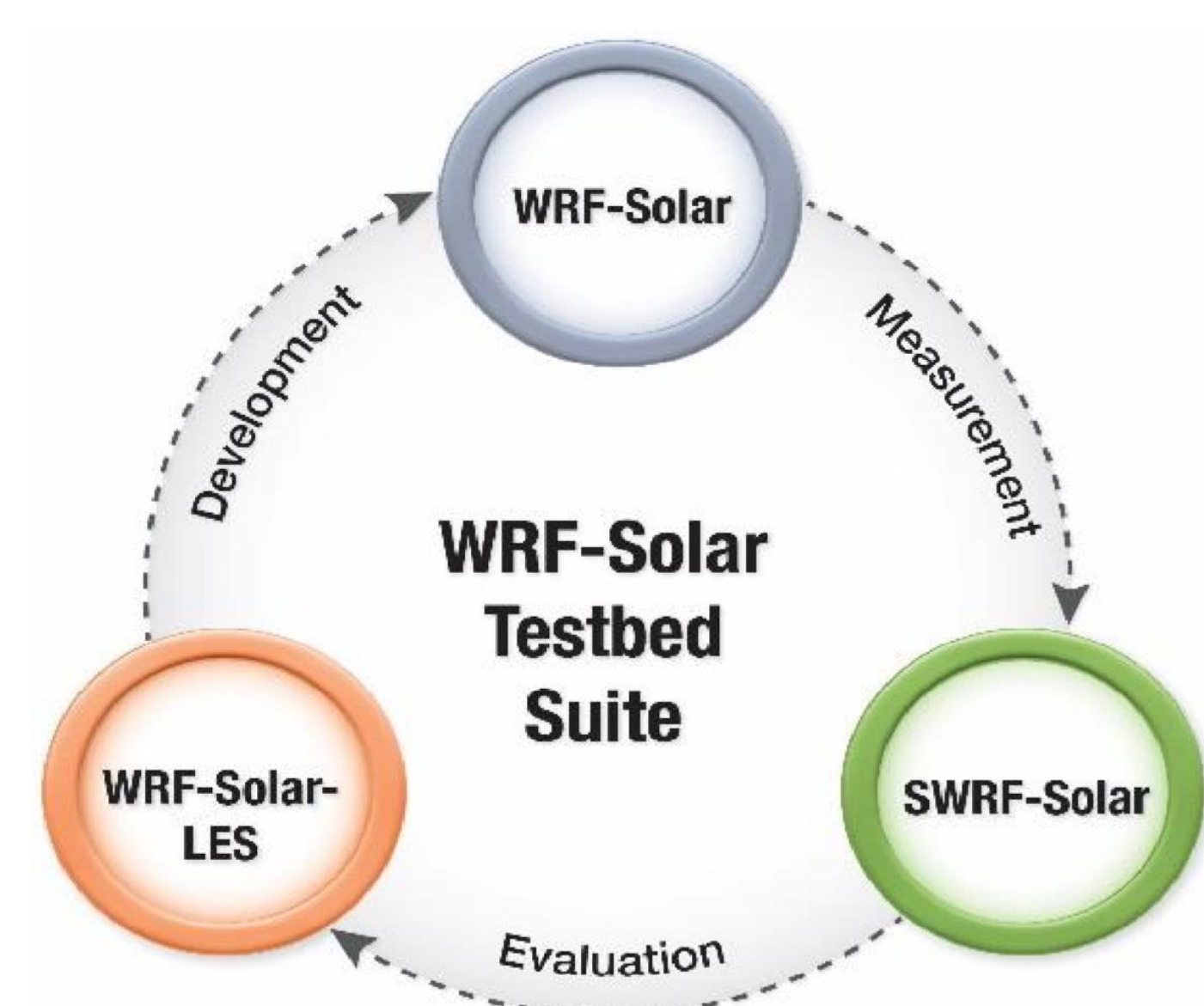


Figure 1. WRF-Solar suite, the modeling framework.

WRF-Solar :

- Solar energy applications
- Aerosol-radiation feedbacks
- Aerosol indirect effect
- Fully coupled aerosol-cloud-radiation system

Three configurations:

- Nested WRF-Solar (3km grid)
- Large eddy simulation (LES)
- Single column model (SWRF)

Evaluation metrics suite: Mean bias, Standard deviation, Correlation coefficient, RMSE, Percent error and Relative Euclidean distance (D).

$$D = \sqrt{\left(\frac{\bar{x} - \bar{y}}{\bar{y}}\right)^2 + \left(\frac{\sigma_x - \sigma_y}{\sigma_y}\right)^2 + (c_{xy} - 1)^2}$$

Indirect Aerosol Effects

First: CCN↑ → Nc ↑ → mean volume radius ↓ → effective radius ↓ → cloud optical depth ↑ → relative cloud radiative forcing (RCRF) ↑ → SW@surface ↓

$$RCRF = (F_{all} - F_{clear})/F_{clear}$$

Second: CCN↑ → Nc ↑ → mean volume radius ↓ → autoconversion ↓ → precip efficiency ↓ → cloud duration, fraction, LWP ↑ → SW@surface ↓

Cloud Fraction & Solar Irradiance

Cases @ ARM SGP facility: Sc on 2009-05-06; Cu on 2016-06-19

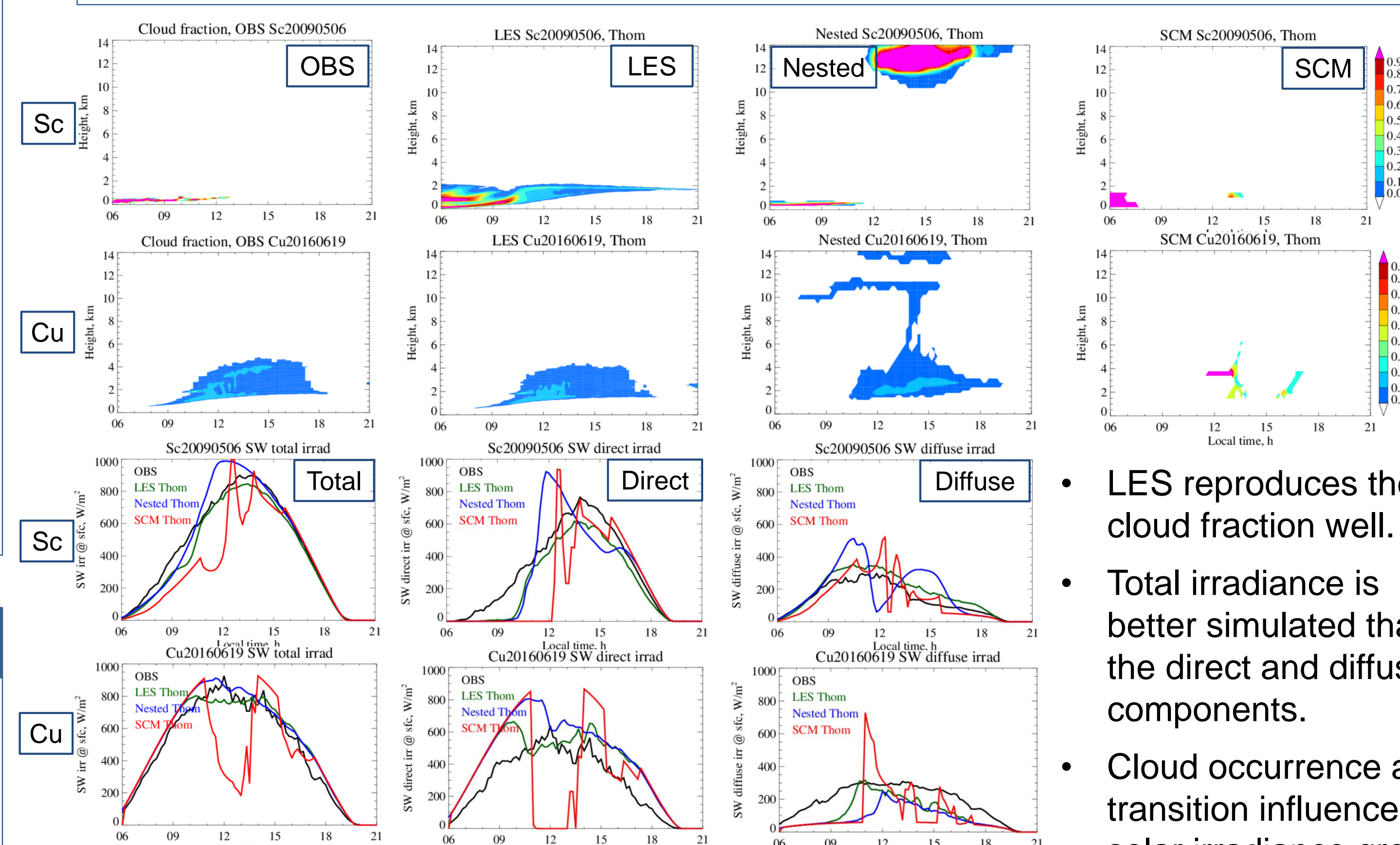


Figure 2. Comparison of simulated clouds and solar irradiance to observation.

Sensitivity of Solar Irradiance to Microphysics

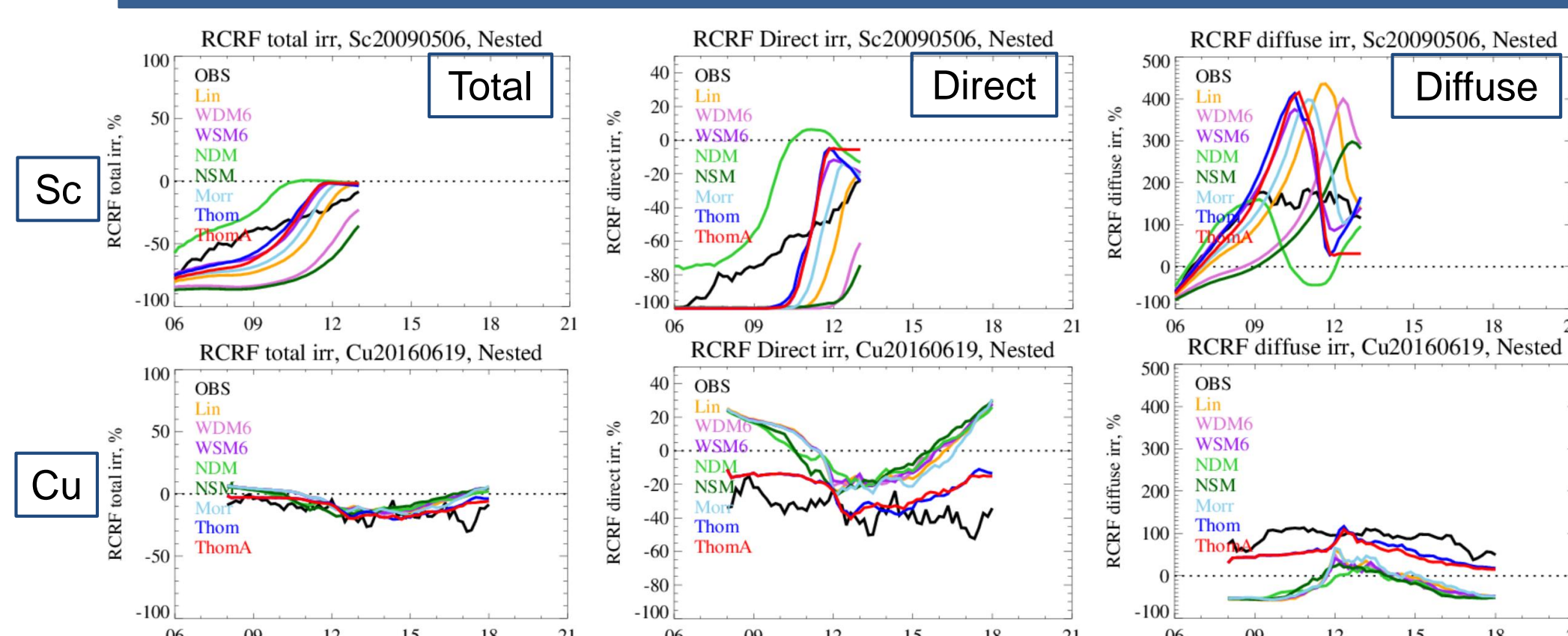


Figure 3. Relative cloud radiative forcing using different cloud microphysics.

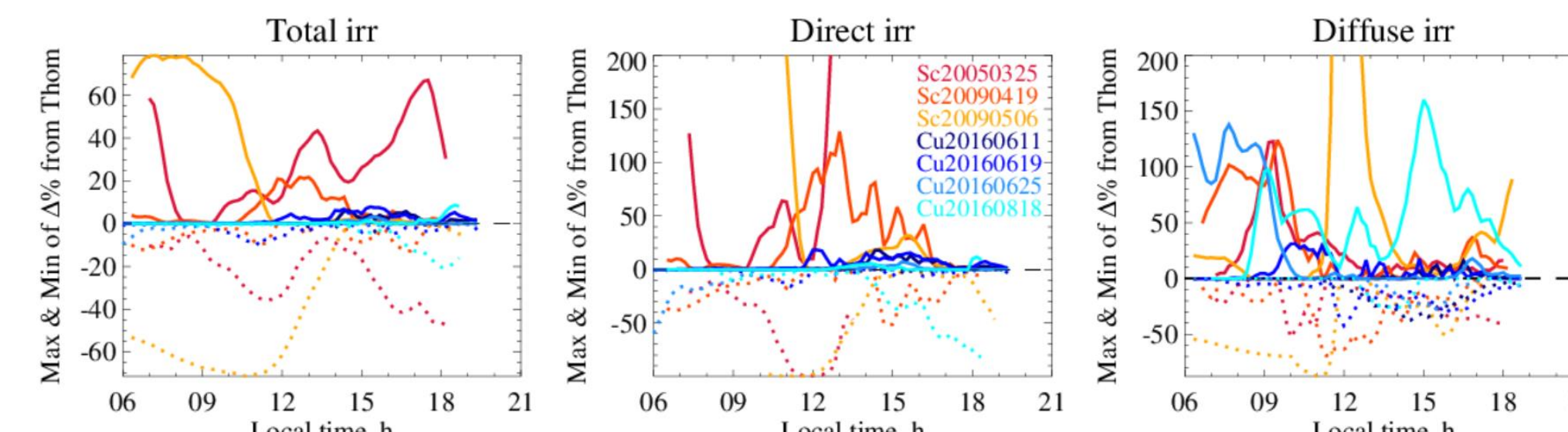


Figure 4. Maximum and minimum difference in solar irradiance from the baseline simulation using Thompson scheme (Thom) for different cloudy cases.

Influence of Cloud Water

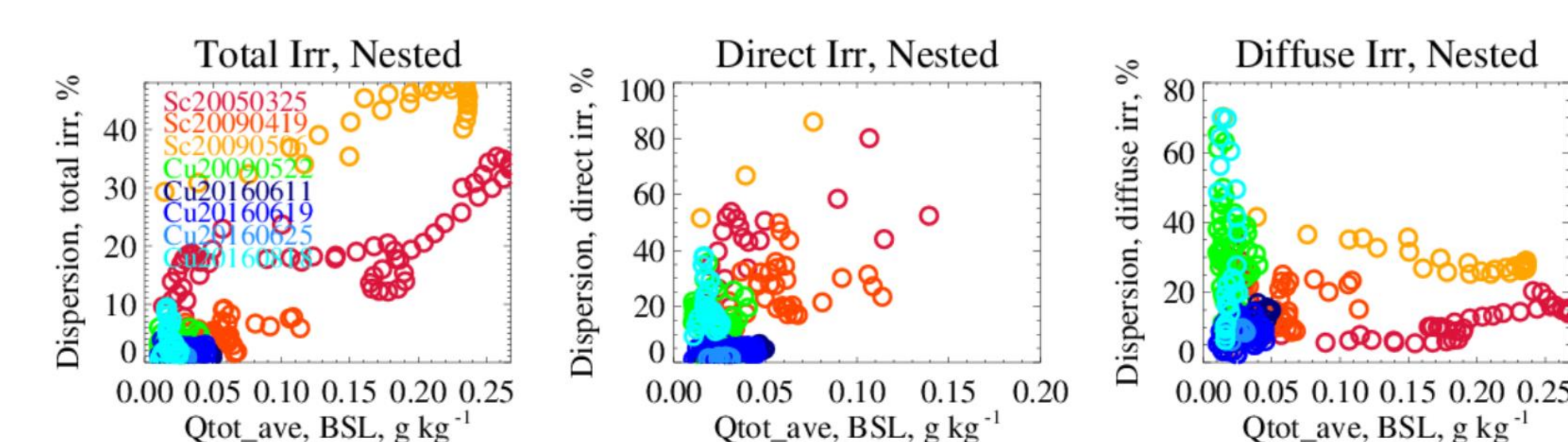


Figure 5. Dispersion in solar irradiance using different microphysics v.s. averaged total cloud water mixing ratio.

Aerosol Indirect Effect

Thompson aerosol aware scheme (ThomA) with different aerosol inputs

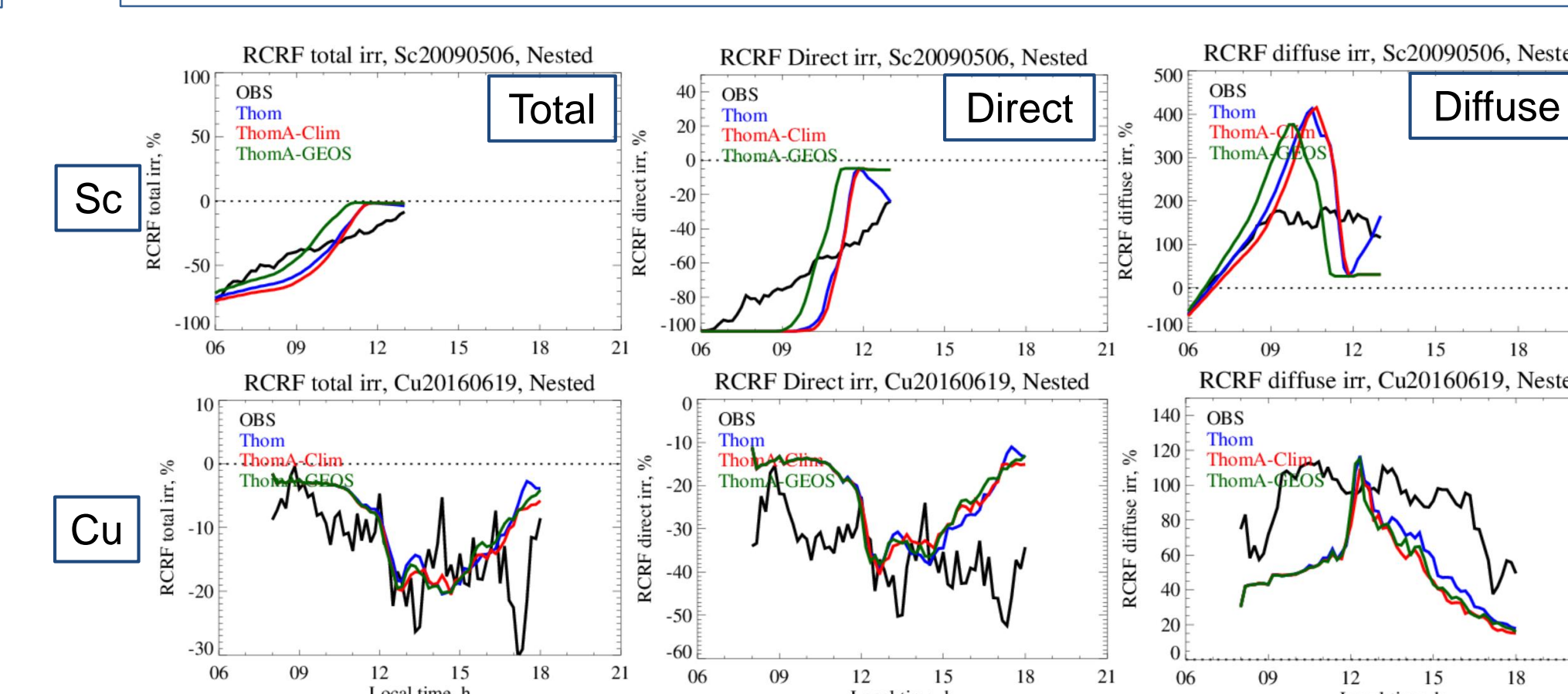


Figure 6. RCRF with different aerosol inputs. ThomA-Clim has larger aerosol # conc and ThomA-GEOS has smaller aerosol # conc.

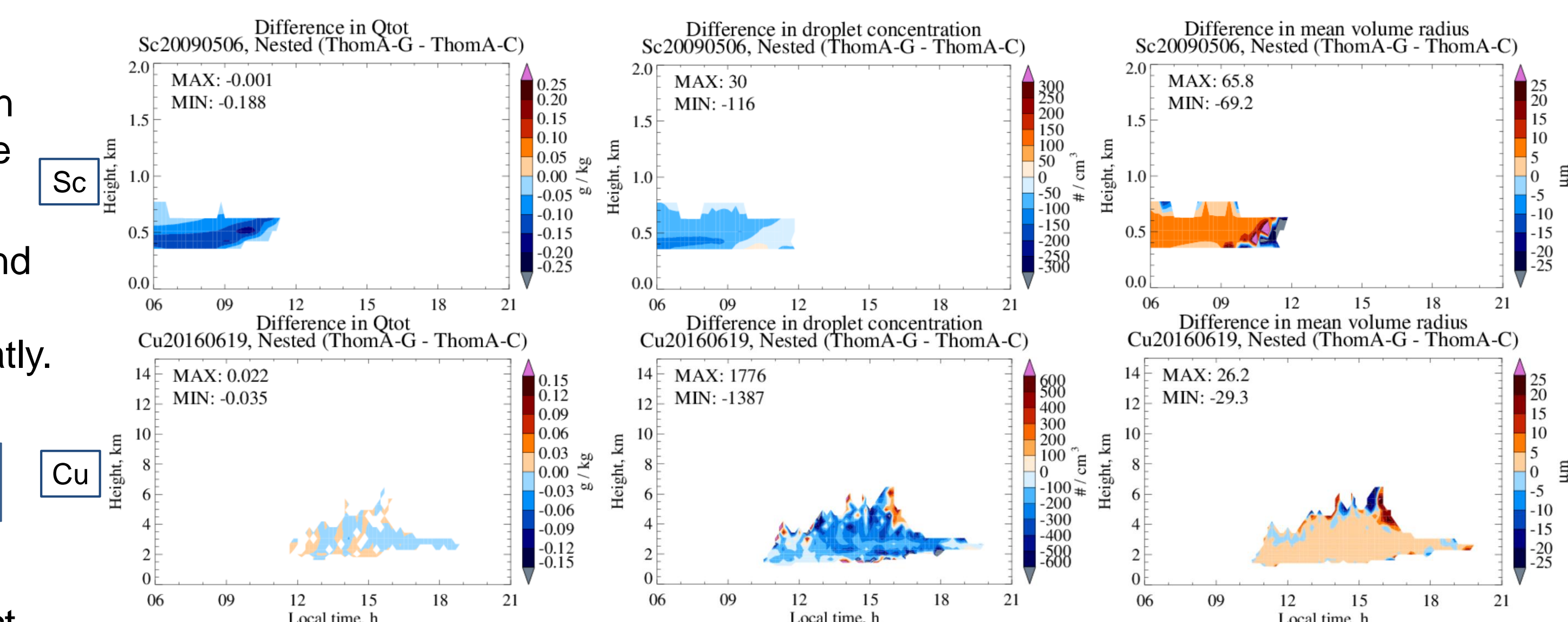


Figure 7. Comparison of cloud properties with different aerosol inputs.

Model Performance

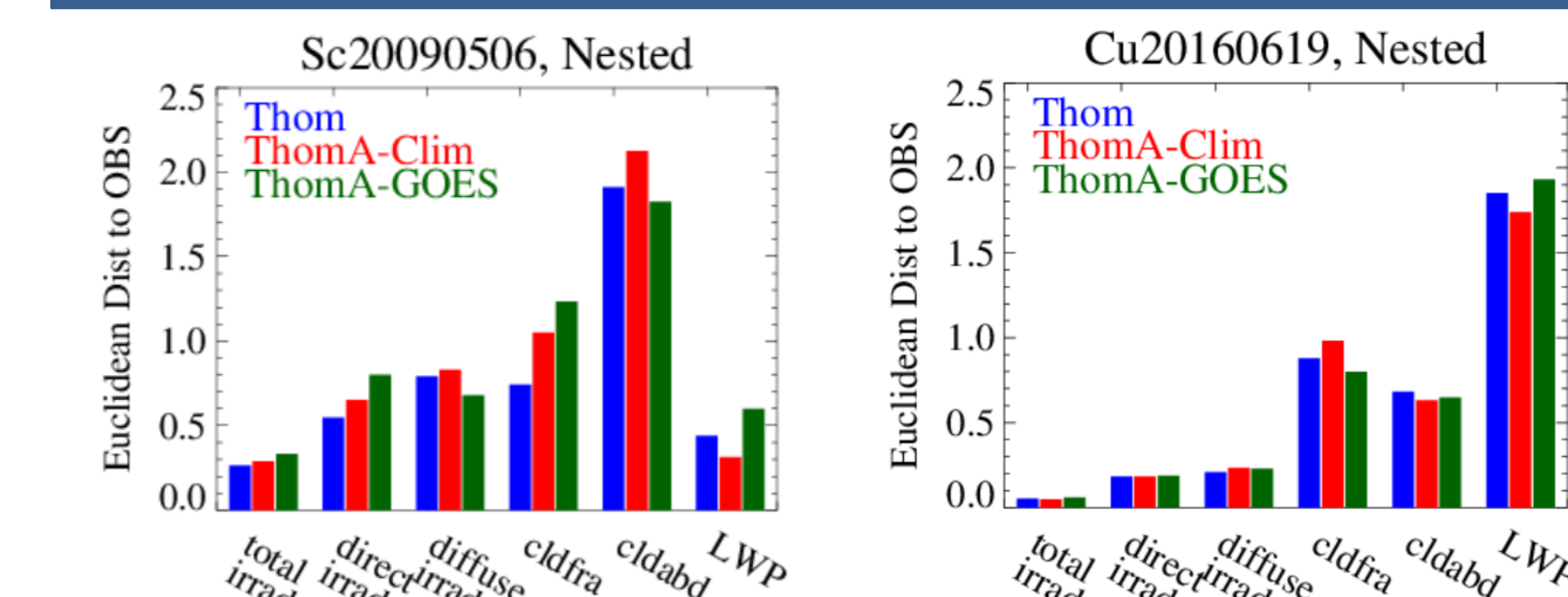


Figure 8. Relative Euclidean distance of radiative and cloud properties.

Conclusions

- Total irradiance appears reasonable due to cancellation of model biases in direct and diffuse irradiances.
- Model simulates better radiative properties than cloud properties.
- Model simulates better solar irradiance in Cu cases than in Sc cases.
- Different microphysics schemes lead to a significant spread of simulated solar irradiance, especially in the Sc cases.
- Different aerosols lead to differences in clouds and solar irradiances.
- Ongoing work on improving cloud microphysics and radiative transfer.

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References

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Wu, W., Y. Liu, and A. K. Betts, 2012: Observationally based evaluation of NWP reanalyses in modeling cloud properties over the Southern Great Plains. *Journal of Geophysical Research: Atmospheres*, **117**, doi:[10.1029/2011JD016971](https://doi.org/10.1029/2011JD016971).

Acknowledgements

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