# The Ice Cloud Radiative Effect Estimated with Retrieved Ice Particle Roughness Based on MISR and MODIS Measurements

1067

Yi Wang[1], Souichiro Hioki[1], Ping Yang[1], Larry Di Girolamo[2], Dongwei Fu[2]

1 Department of Atmospheric Sciences, Texas A&M University, 2 Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign

## 1. Background and methods

**Background:**

Current operational satellite retrieval algorithms commonly assume that ice cloud pixels are horizontally homogeneous with no variation in the ice particle shape. For example, a hexagonal aggregate column ice particle model with moderate roughness ($\sigma^2 = 0.5$) is used in MODIS collection 6 products.

**Scientific Question:**

How do the retrieved ice cloud properties and associated cloud radiative effect change when taking variant ice particle shape assumption in satellite retrievals?

**Data and Methods:**

The Multi-angle Imaging SpectroRadiometer (MISR) instrument (Diner, et al. 1998) has nine cameras that view clouds with a wider range of scattering angles than the MODIS sensor with a nadir camera only.

Therefore, it is possible to check the consistency of an ice particle model over a wide range of scattering angles by using multi-angle observations from the MISR.

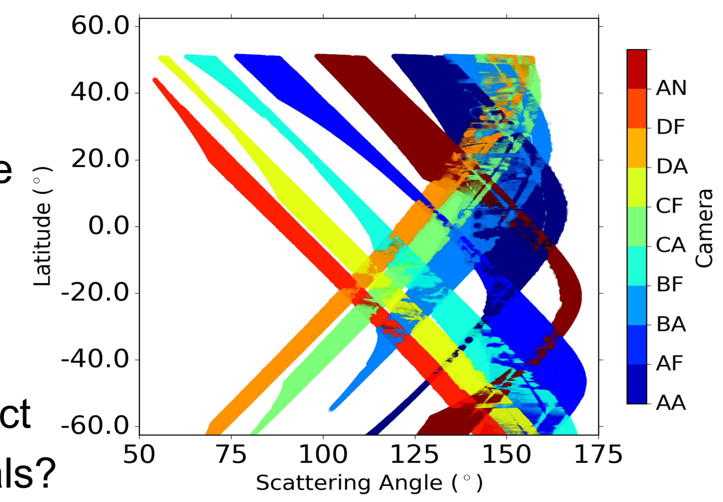


**Fig. 1.** MISR camera names and their viewing scattering angles as a function of latitude during 2013 December solstice day from the MISR-MODIS fused datasets over ocean. AN is the nadir camera. Pixels with sun glint angle less than 35° are removed.

The consistency of multi-angle reflectivity radiative transfer simulations and satellite measurements is evaluated by applying spherical albedo differences method (Doutriaux-Boucher, et al. 2000) to data from the MISR sensor.

Ice cloud thickness and effective radius are retrieved using bi-spectral shortwave retrieval technique (Nakajima, and King, 1990) based on reflectivity of MODIS from MISR and MODIS collocated dataset.

## 2. Seasonal variations of ice cloud property retrievals

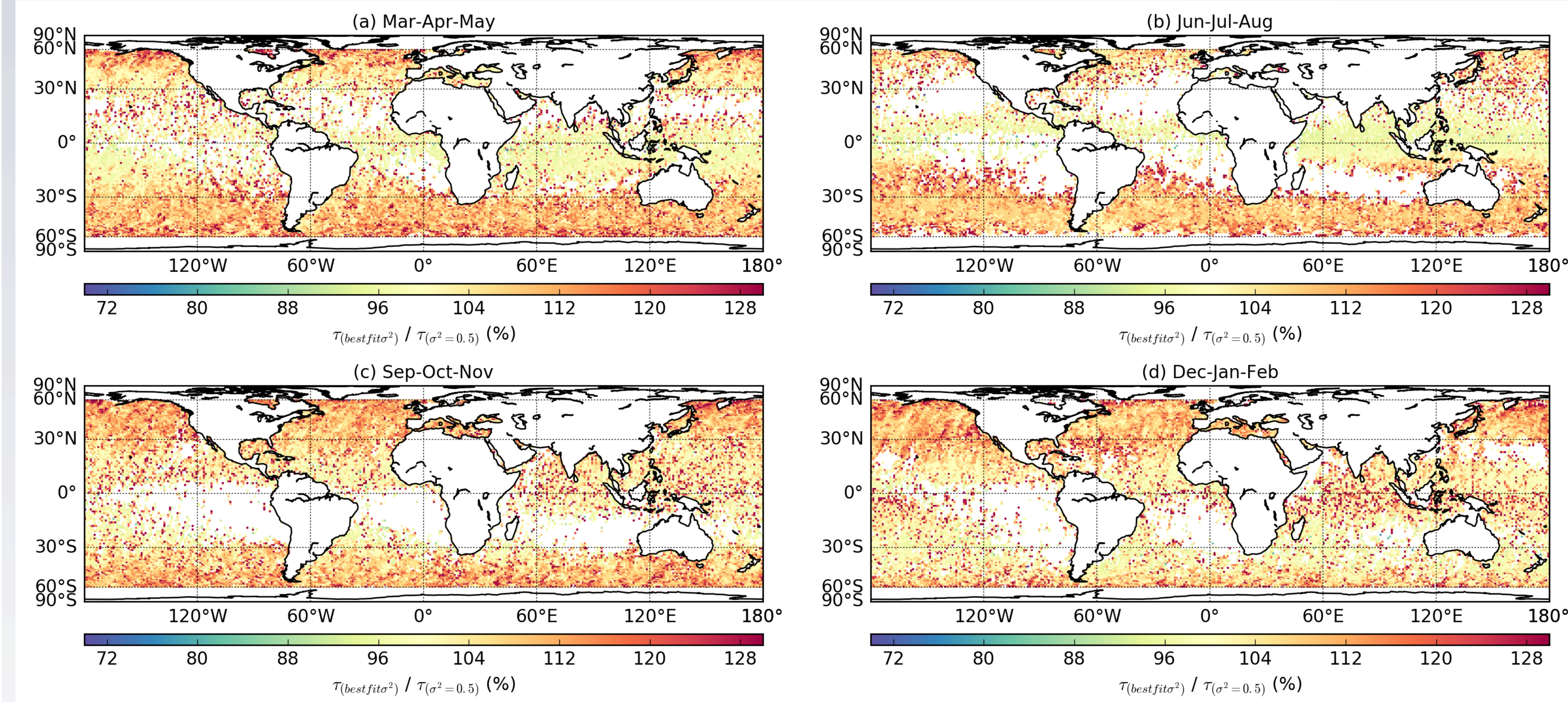


**Fig. 2.** Global distribution of the ratio of ice cloud optical thickness with best-fit roughness ($\sigma^2$) to ice cloud optical thickness with 0.5 roughness ($\sigma^2 = 0.5$, same as MODIS collection 6 products) in (a) MAM, (b) JJA, (c) SON, and (d) DJF.

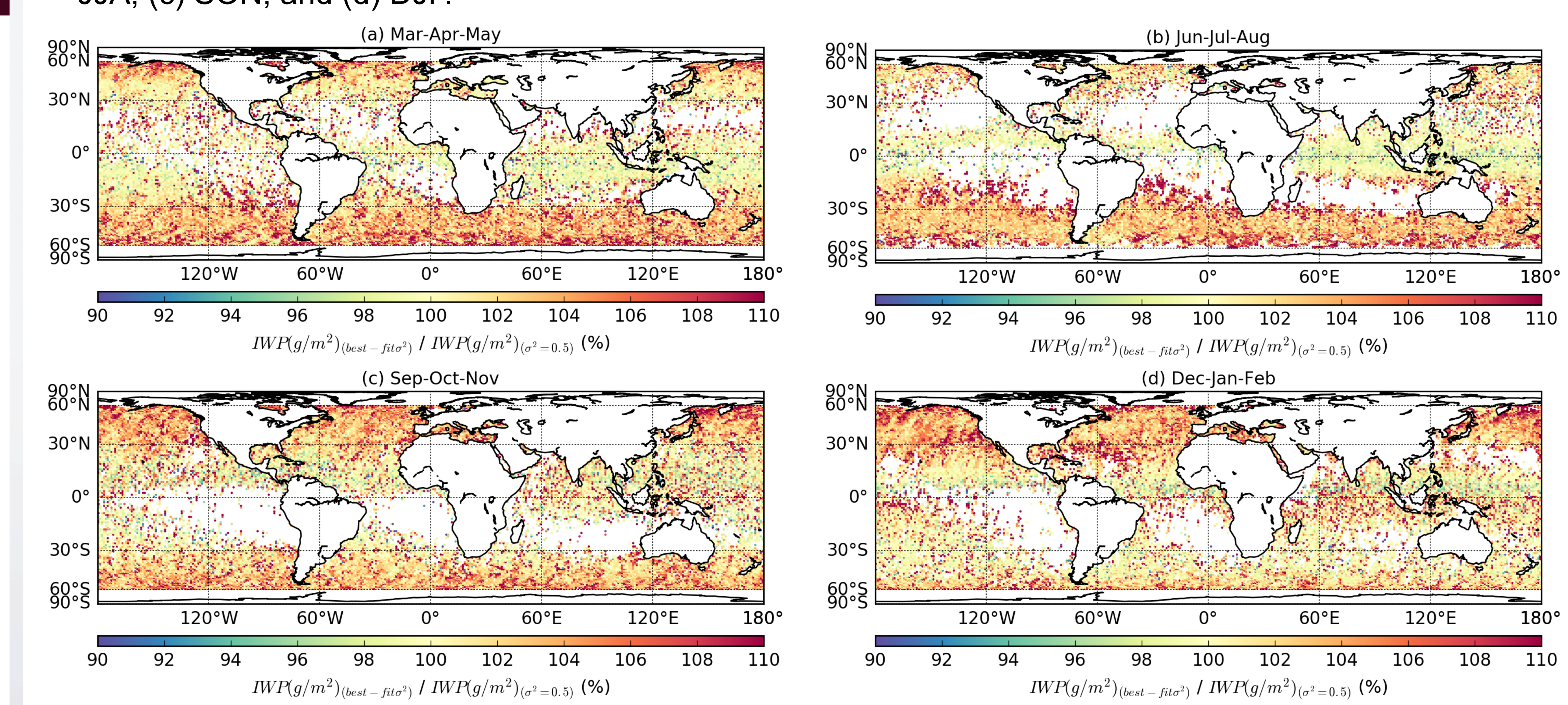


**Fig. 3.** As in Fig. 2, but for ice water content in (a) MAM, (b) JJA, (c) SON, and (d) DJF.

## 3. The influence of solar zenith angle on retrievals

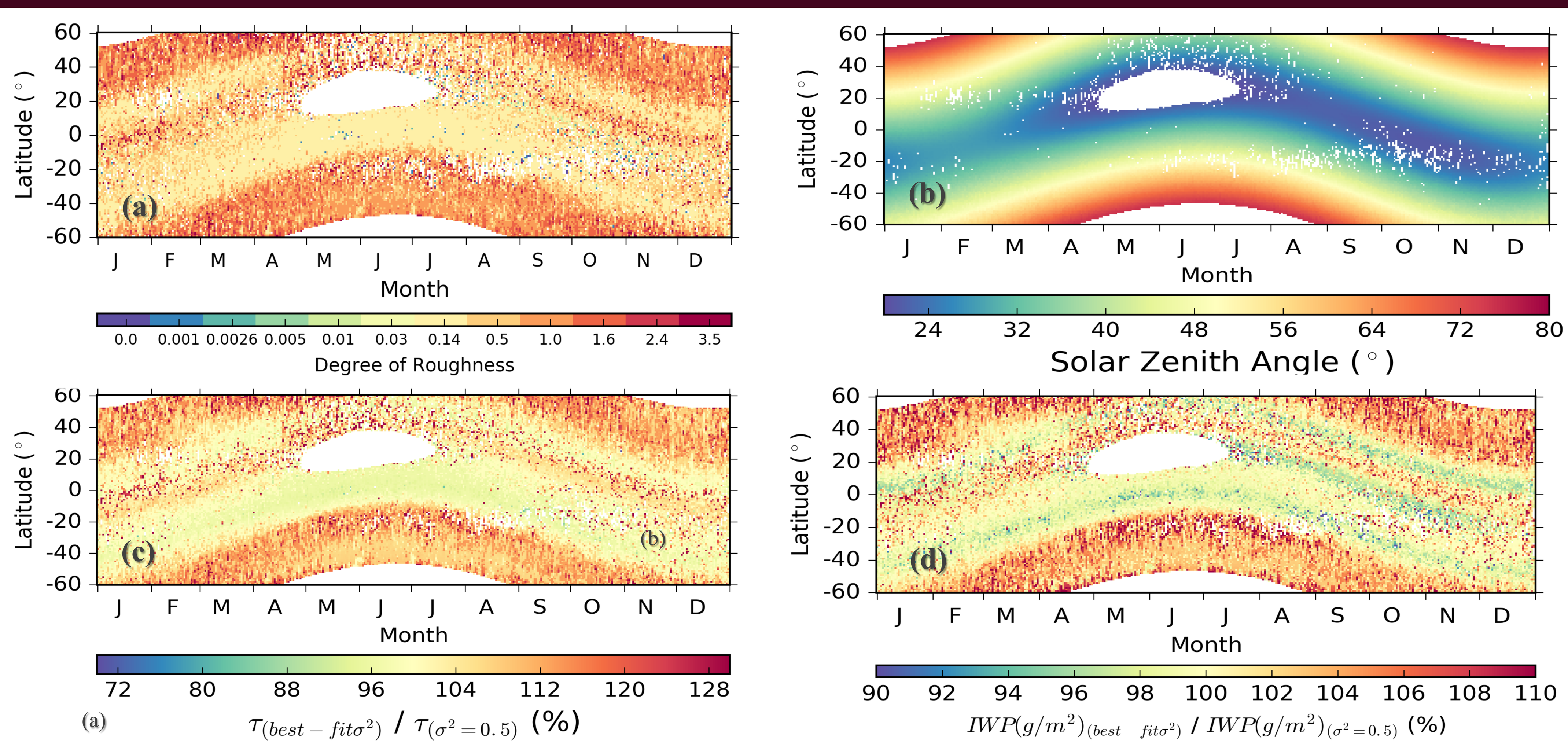


**Fig. 4.** Latitudinal-median (a) ice cloud particle surface roughness, (b) solar zenith angle (SZA), (c) ice cloud optical thickness (as in Fig 2), (d) effective radius (as in Fig 3) as a function as a function of latitude and day of the year.

The monthly variations of ratio of best-fit ice particle surface roughness retrievals to 0.5 roughness retrievals are associated with the monthly shift of solar zenith angle (SZA).

## 4. Seasonal variations of ice cloud radiative effect

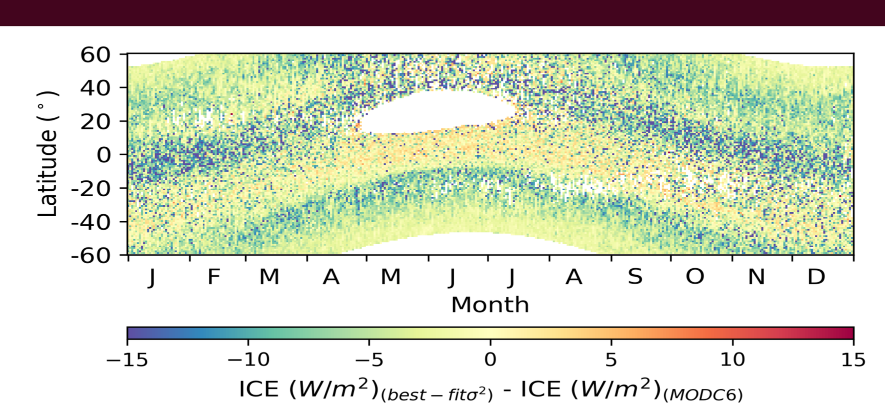


**Fig. 5.** Latitudinal-median difference between shortwave radiative effects of ice clouds at the surface with best-fit roughness and result with 0.5 roughness.

We apply the discrete ordinate solver (DISORT) with 16 streams as the radiative transfer scheme.

As input variables, ice cloud optical thickness and ice water content are based on ice particle model with best-fit roughness (see Section 3).

Ice cloud radiative effect (IRE) is defined as the shortwave flux difference between conditions with and without ice clouds present.

$$IRE = (F_{down} - F_{up})_{all-sky} - (F_{down} - F_{up})_{clear-sky}$$

## 5. Summaries

- Retrievals using multi-angle observations with a wide range of scattering angle show that the best-fit ice particle roughness is primarily a function of SZA. The retrieved median best-fit ice particle has more severe roughness in high Solar Zenith Angles (SZAs) than low SZAs.
- The seasonal variations of the ratio of ice cloud optical thickness and ice water path with best-fit roughness ($\sigma^2$) to ice cloud properties retrievals with 0.5 roughness ($\sigma^2 = 0.5$, same as MODIS collection 6 products) are highly correlated to the seasonal shift of SZA. A high median ratio for ice cloud optical thickness / ice water path more likely occurs in high SZAs.
- Best-fit roughness model estimates higher ice cloud optical thickness and higher ice water path almost always, but especially in high SZAs.
- Compared to ice cloud shortwave radiative effect based on ice cloud property retrievals with best-fit roughness, MODIS collection 6 products underestimate surface cooling effect by ice cloud; i.e., too much shortwave flux reach to the ground for ice cloud in MODIS Collection 6 products.
- Since SZA varies seasonally, these features may improve our understanding on the observed seasonal variations of satellite ice cloud property retrievals and associated cloud radiative effect.

## References and acknowledgements

**Contact Information:** Yi Wang (yiwang_atmo@tamu.edu)

**References**

Diner, D. J., et al. (1998), IEEE Trans. Geosci. Remote Sens. 36.4, 1072-1087.
Doutriaux-Boucher, M. et al. (2000), Geophys. Res. Lett., 27 (1), 109-112.
Nakajima, T. and King, M.D.(1990), J. Atmos. Sci., 47 (15), 1878-1893.
Yang, P. and K. N. Liou (1998), Contrib. Atmos. Phys., 71 (2), 223-248.

**Acknowledgements:** This research supported by NASA Grant NNX15AQ25G and Texas A&M High Performance Research Computing.