# Observed cloud variability and its implications for microphysics and radiation parameterizations

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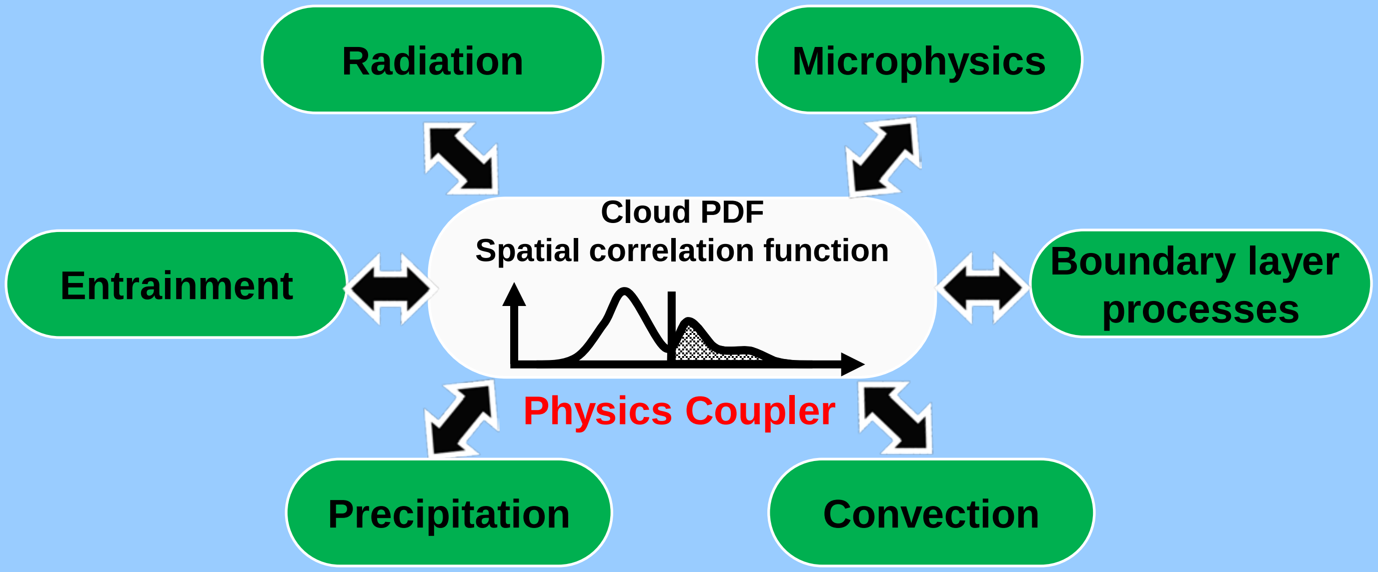
ASR science team meeting, Potomac, MD, 03/11/2014

# Clouds as probability functions



Radiation

Microphysics

Entrainment

Cloud PDF
Spatial correlation function

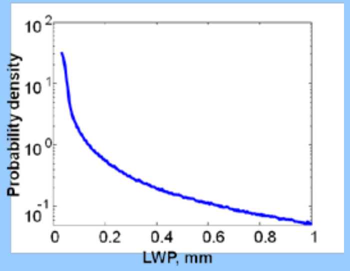
Boundary layer processes

Physics Coupler

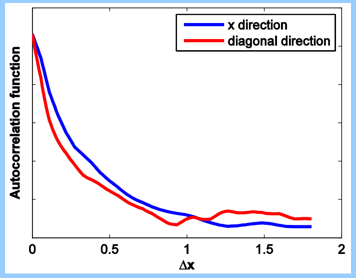
Precipitation

Convection

Use observations to characterize the distribution function



Use high resolution model simulations

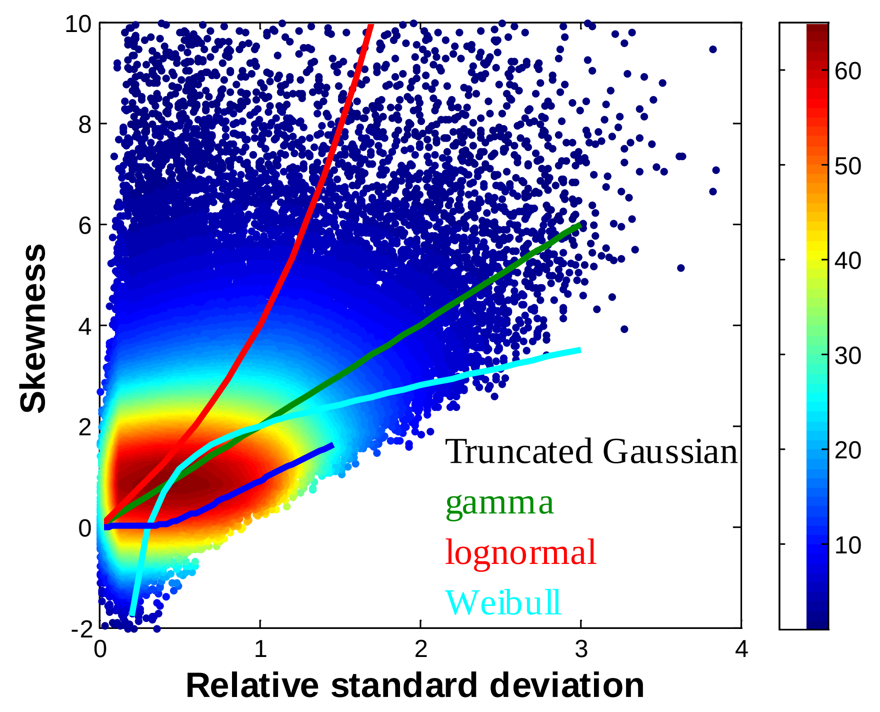


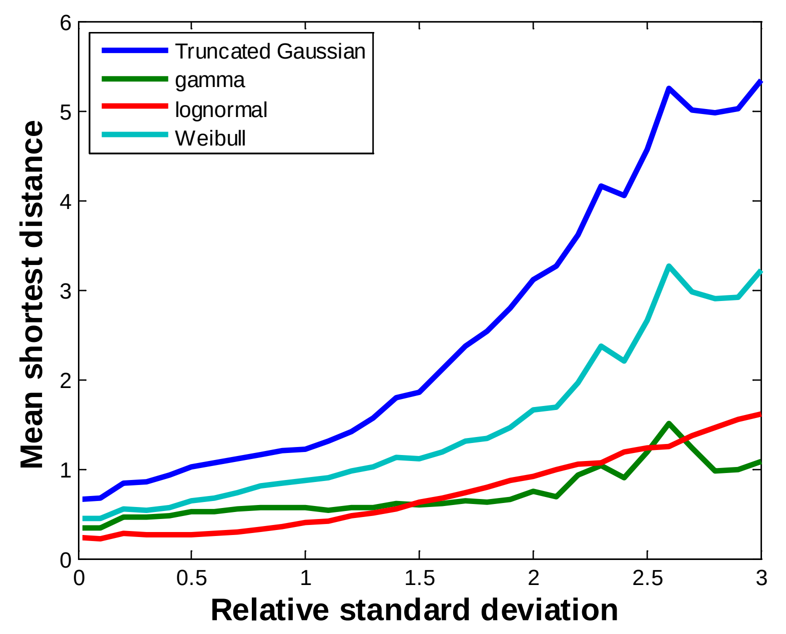
# Which function better describes the observed skewness-relative standard deviation relationship?

ARM microwave radiometer based Liquid Water Path (LWP) retrievals in the TWP, SGP, and NSA sites from 1999 to 2012

LWP<0.03 mm, precipitation-contaminated retrievals are excluded

Statistical moments are calculated in each 3-hour window

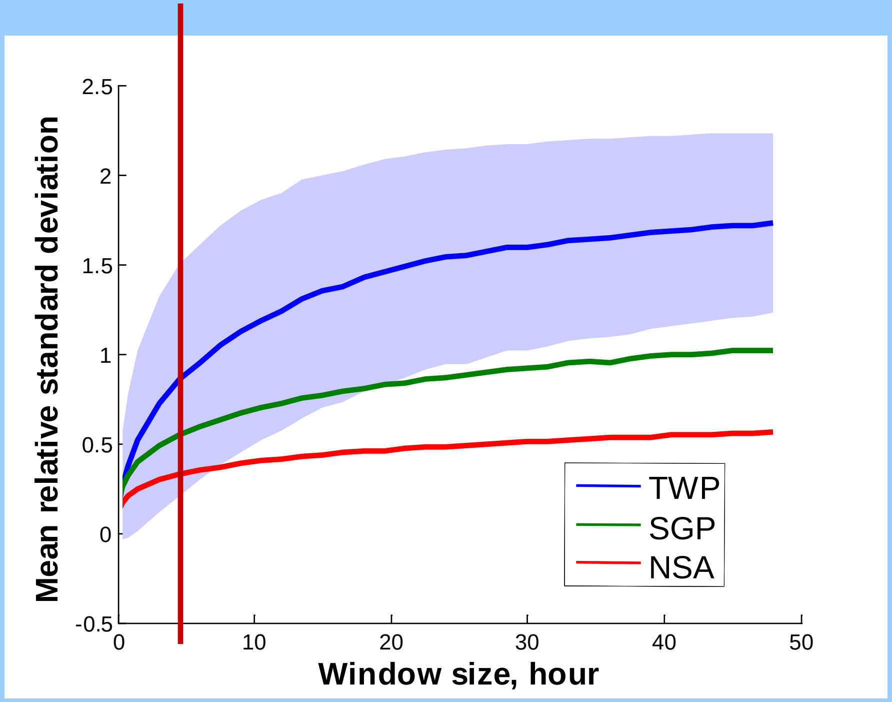


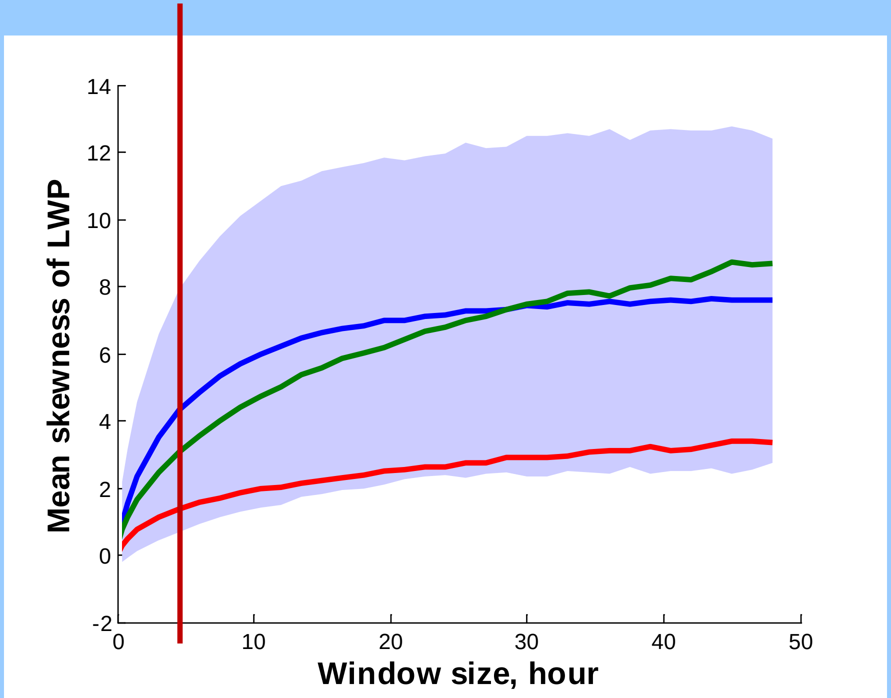


Lognormal and Gamma distributions work best.

# Dependence on window size (scale)

Mean relative standard deviation and skewness increase monotonically with window size, indicating more variability in larger windows.





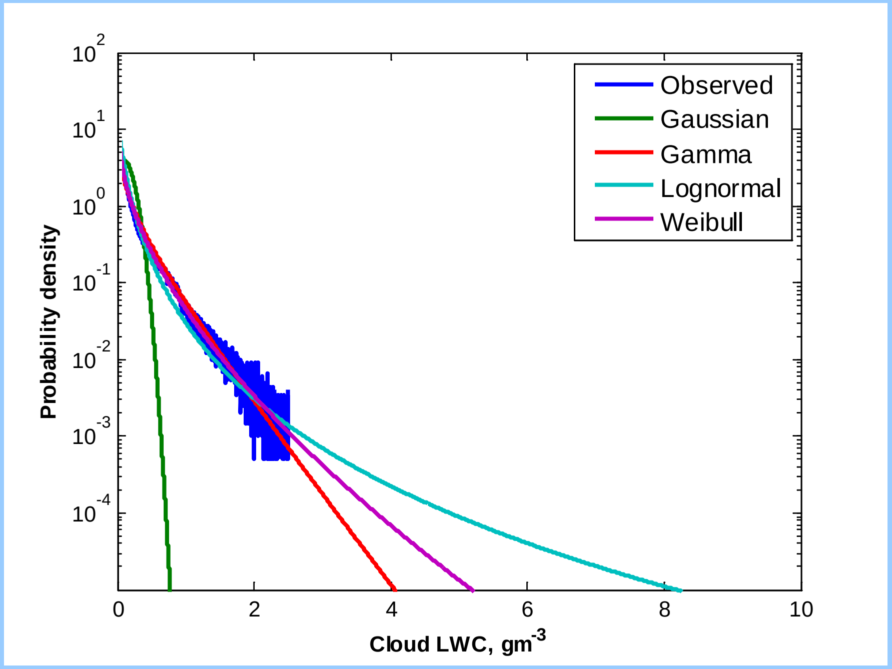
# Effects of subgrid cloud variability on grid-average autoconversion rate

Vertically-averaged cloud liquid water content from MICROBASE

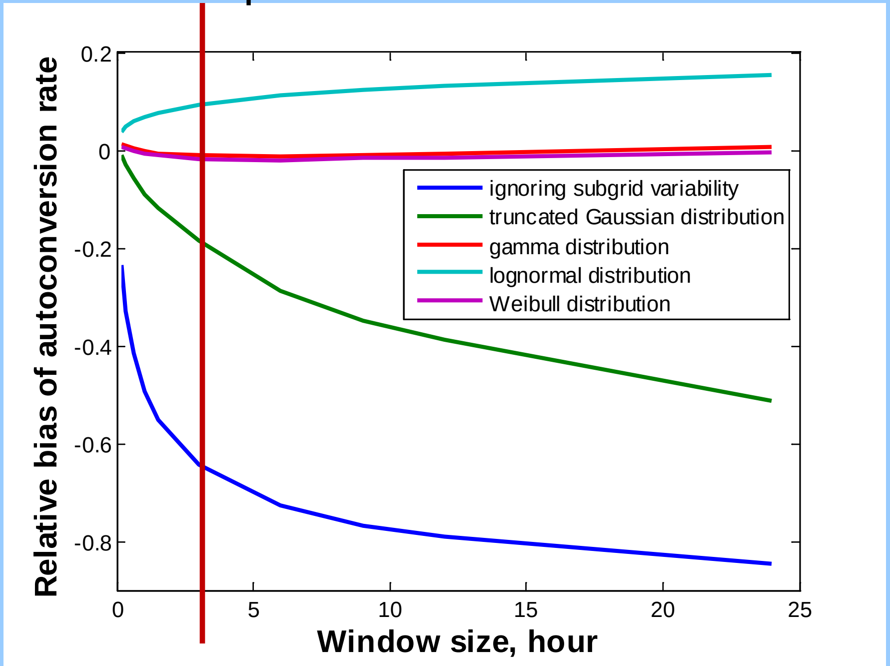
Approximate the observed PDF using heavily-tailed distributions by forcing them to conserve the observed first two moments

Independent column approximation (ICA)

Observed and derived PDFs



Scale-dependence of the mean bias



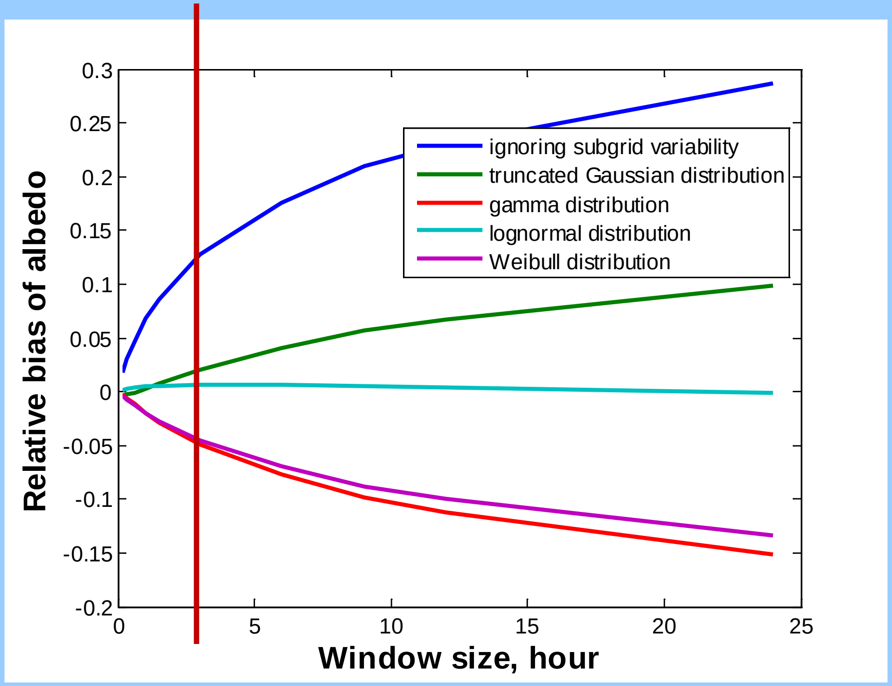
Gamma and lognormal distributions produce minimum bias.

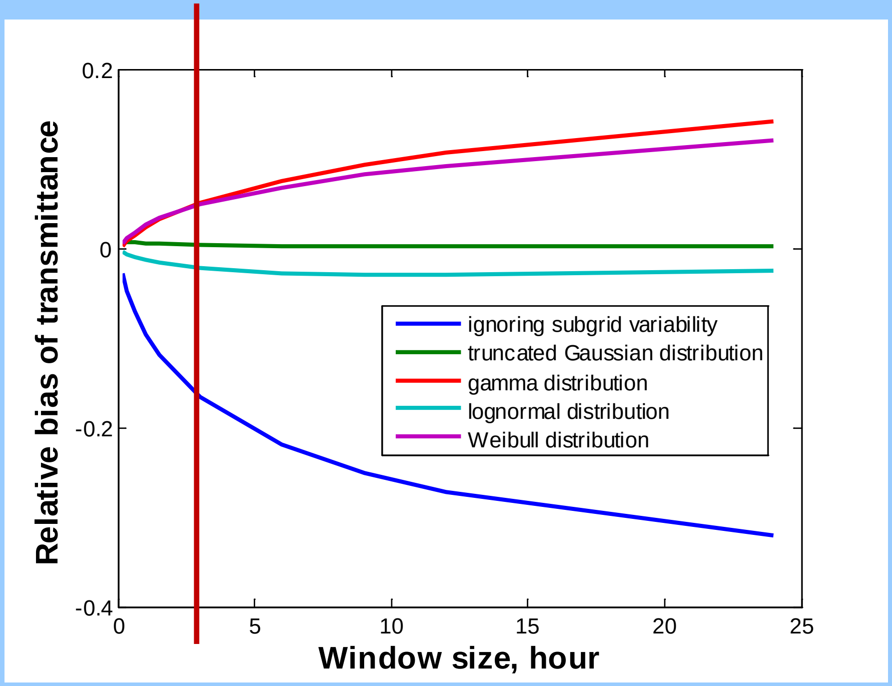
# Effects of subgrid cloud variability on grid-average radiative fluxes

Independent column approximation (ICA)

Re=8 µm, $\omega$=1.0, SZA=30º

No gas scattering, no aerosol, ideally black surface

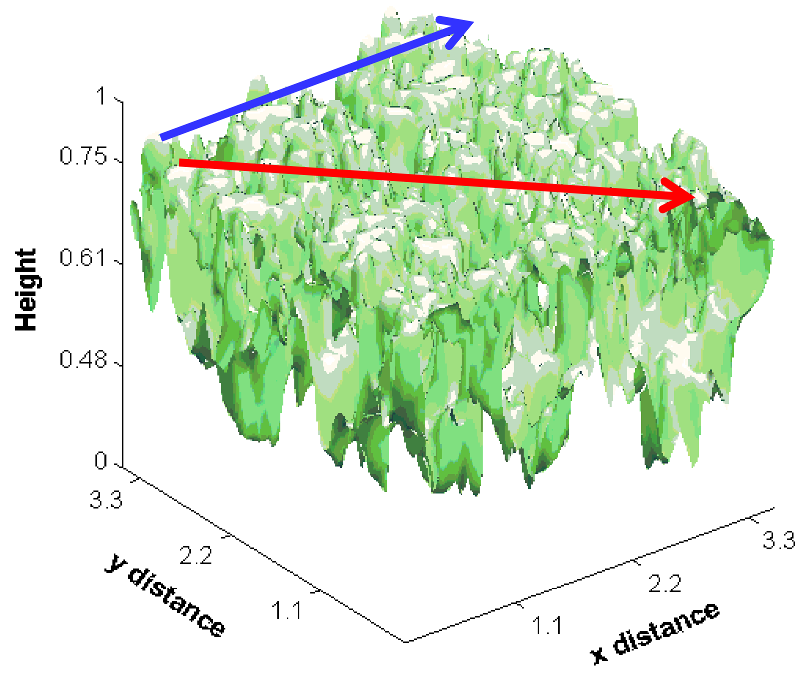


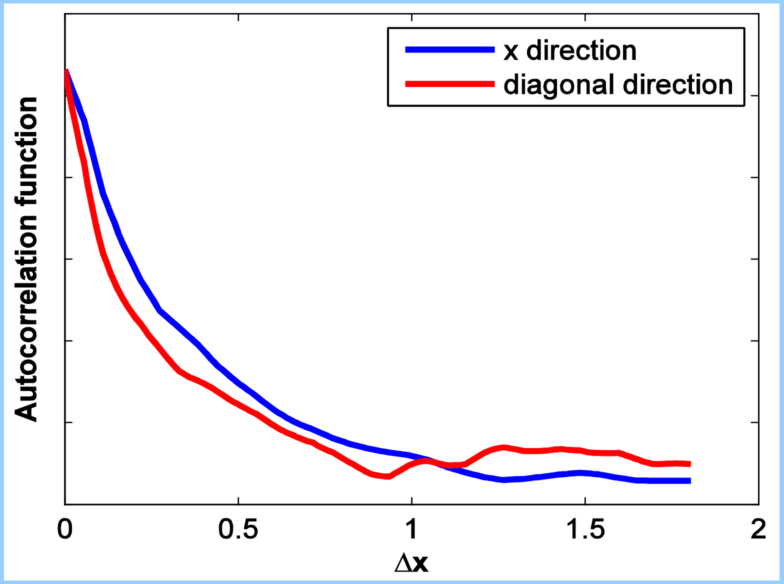


Lognormal distribution works best for radiative fluxes.

# Represent subgrid-scale cloud structure with two-point statistics

A two-point spatial correlation function provides a statistical description of cloud structure. It encodes the most important information for cloud-radiation and cloud-environment interaction, e.g., cloud size, separation distance, organization, and periodicity.





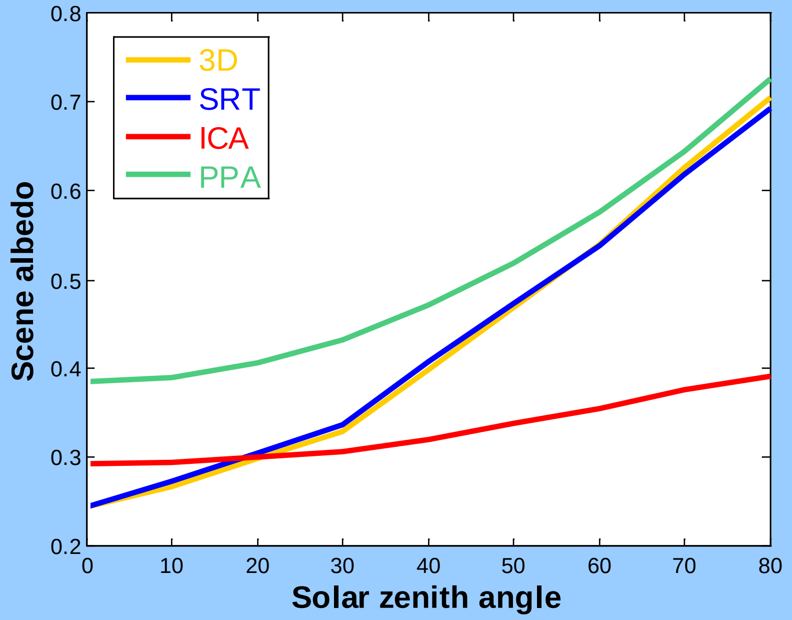
# Introduce cloud structure into radiative transfer parameterizations

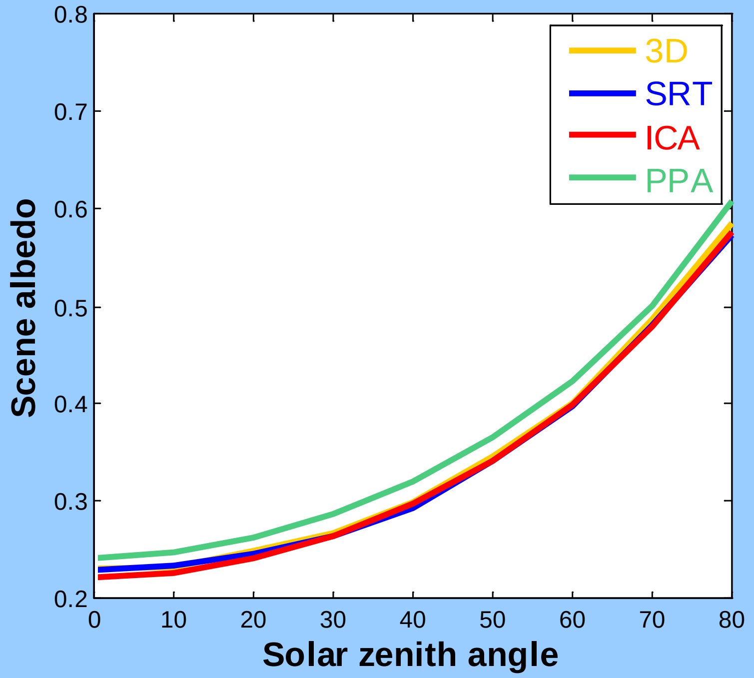
Use statistical-physics-like approaches to reduce 3D transfer equation into 1D

Spatial correlation function is naturally introduced

Capture 3D effects (horizontal transport) effects with 1D equation (SRT)

Several orders fast than 3D code and ICA





# Summary and future directions

Cloud variability increases monotonically with scale.

Highly non-linear processes such as autoconversion are depended on either the left of right tail of PDF, not its mean property.

Using heavily tailed distributions to represent subgrid clouds greatly reduces the bias in grid-average microphysical  process rate and radiative fluxes.

Subgrid cloud structure can be statistically described by a two-point spatial correlation function.

We will develop a suite of microphysical and radiative transfer parameterizations based on the new statistical cloud representation and test them in large-scale and LES models.