A45Q-2081: Seeking guidance from active cloud observations to improve climate model subcolumn generators

Lazaros Oreopoulos (NASA-GSFC), Nayeong Cho (NASA-GSFC and UMBC), Dongmin Lee (NASA-GSFC and Morgan State)
Matthew Lebsock (JPL), Zhibo Zhang (UMBC)

What the work is about

Evaluation two stochastic subcolumn generators:

- SCOPS of COSP (citation)
- "Raisanen" by Räisänen et al. (2004)

These generators are used in GCMs to emulate subgrid cloud variability

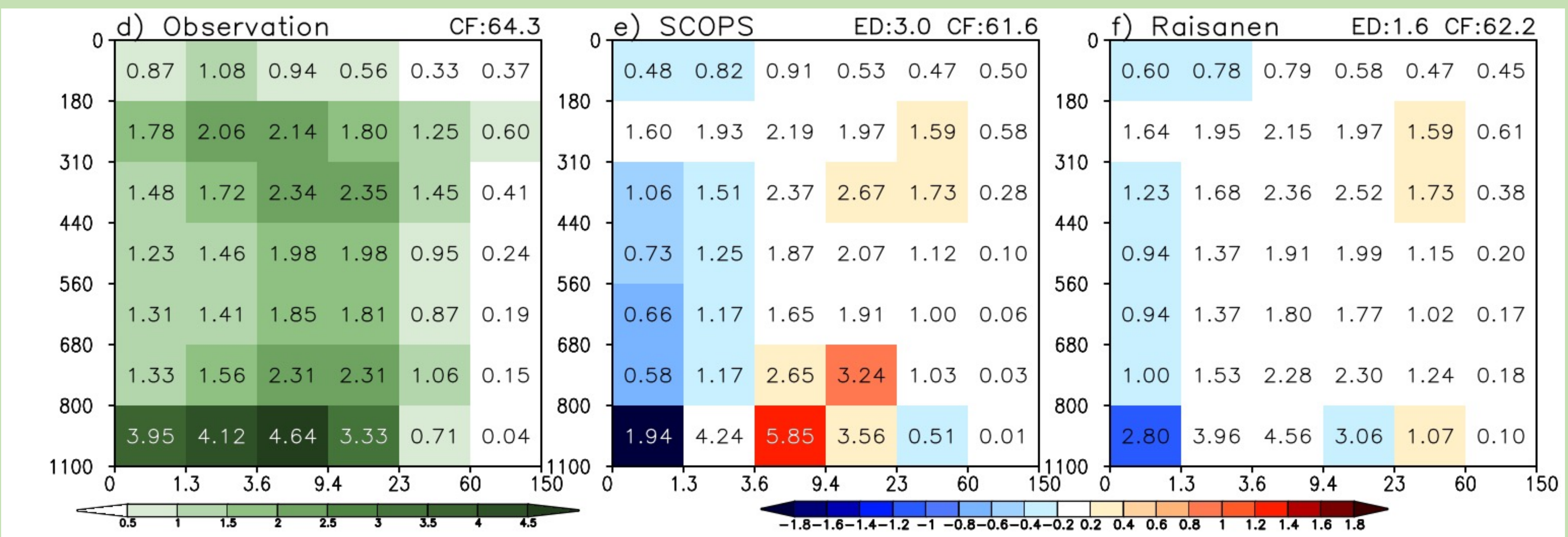
Datasets and methods

Subgrid variability "truth": *Modified* CloudSat-CALIPSO (CC) dataset combining two CC cloud products providing one-year ocean-only two-dimensional (height-distance) cloud optical depth variability of liquid, ice, and mixed phase clouds when blended at scales ~200 m (vertical) and ~ 2 km (horizontal). Dataset is segmented to 100-subcolumn individual "scenes". Mean properties of the cloud fields are passed as input to generators to produce scene-level cloud subgrid variability.

Evaluation: Comparison of cloud fraction (CF) joint histograms in cloud top pressure (CTP) – cloud optical thickness (TAU) space: individual scenes and grand-averages.

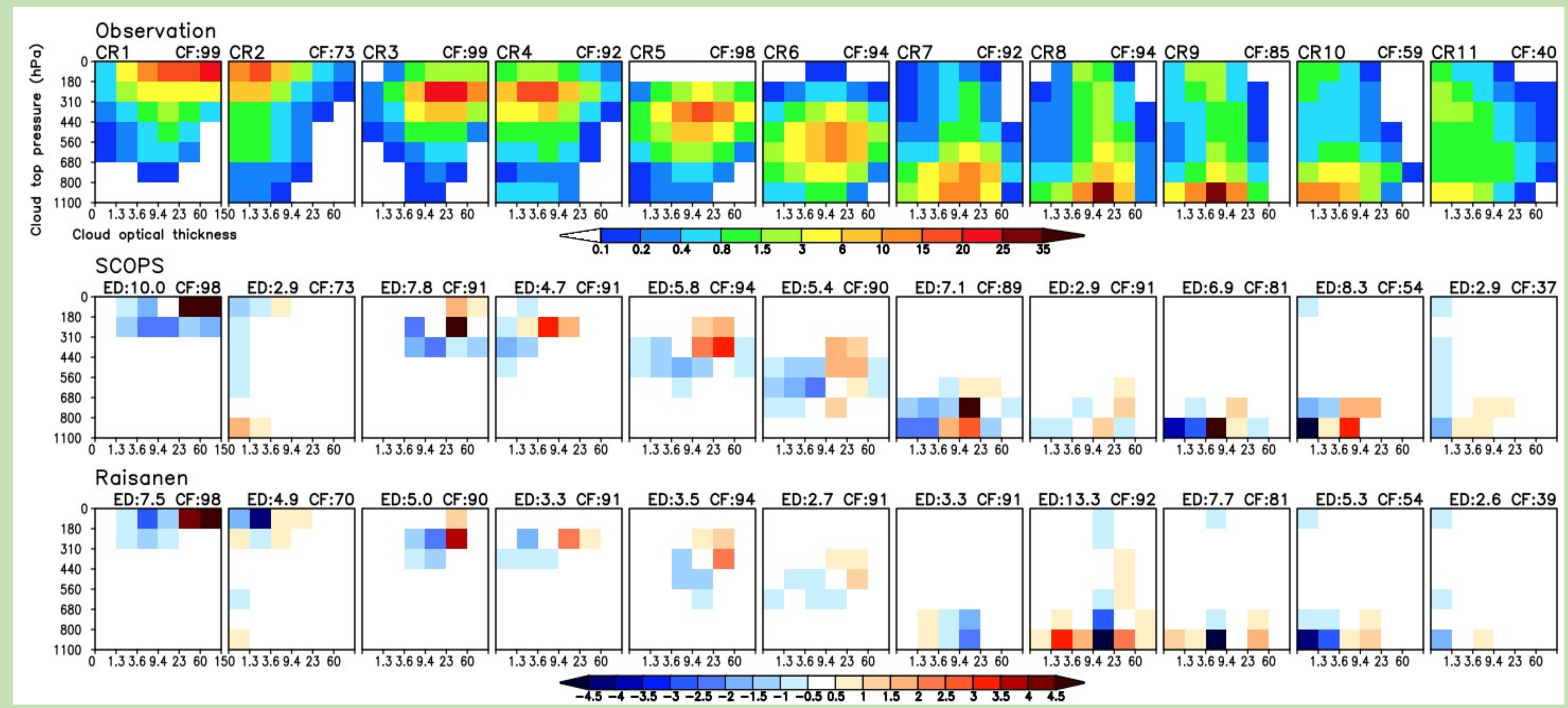
Overall performance

Global Joint Histograms



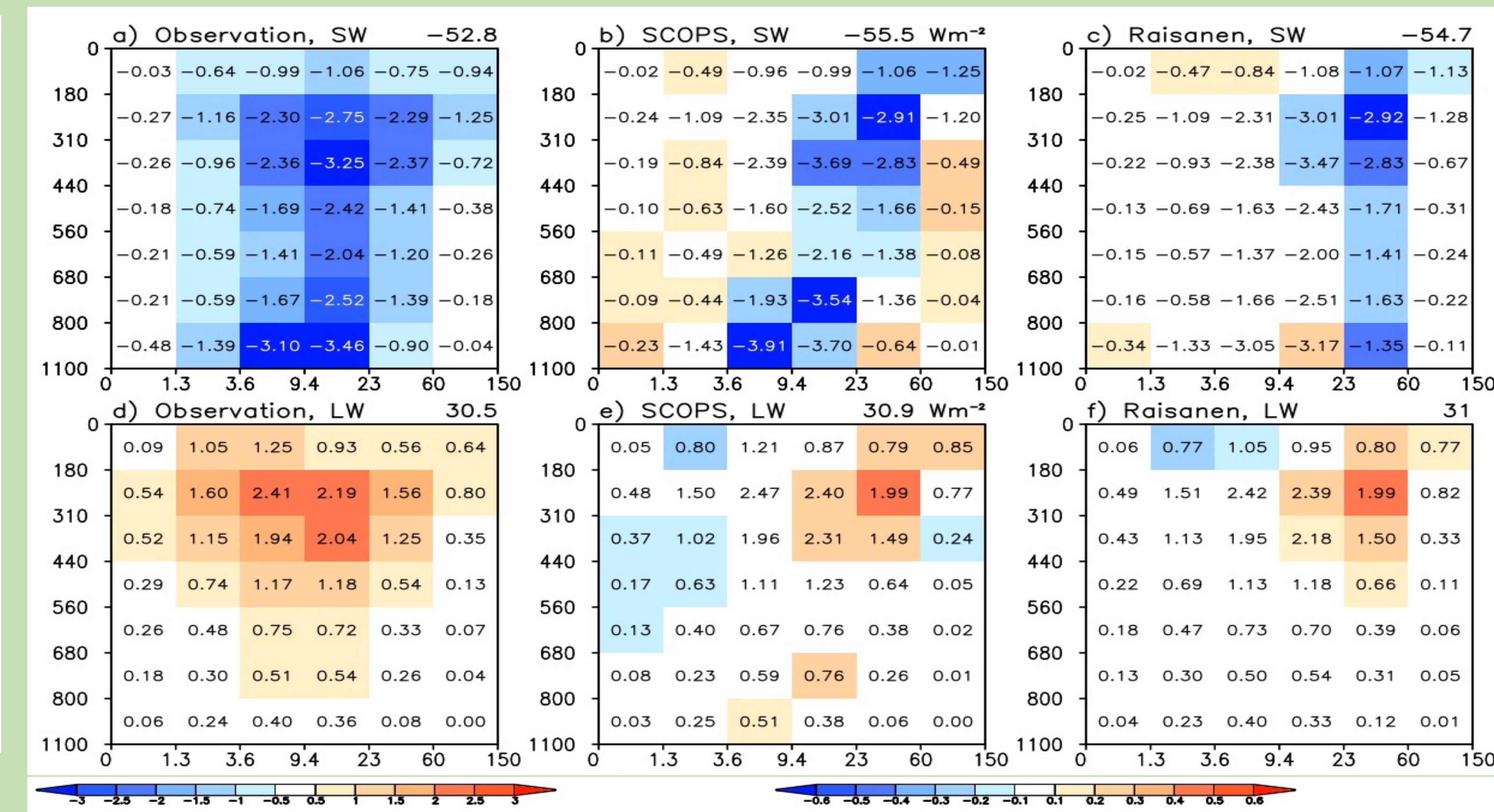
The all-encompassing measure of quality of simulated joint histograms is the Euclidean Distance (ED) from the observed histogram. According to that metric, for the global oceans ***the Raisanen generator performs better*** (ED = 1.6 < ED = 3.0 for SCOPS; compare the right and middle panels where the numbers show bin CF values and the colors errors). Raisanen's total vertically projected CF is slightly closer to observations (but both generators are good). The underestimation by the generators suggest that they ***overlap clouds slightly more maximally than in observations*** which probably also explains the underestimate of optically thin (TAU < 3.6) clouds: the greater vertical cloud alignment of maximum overlap reduces the probability of optically thin clouds. The colored bins in the panel (e) and (f) joint histograms are CTP-TAU combinations of biggest bin CF errors.

Joint histograms by Cloud Regime



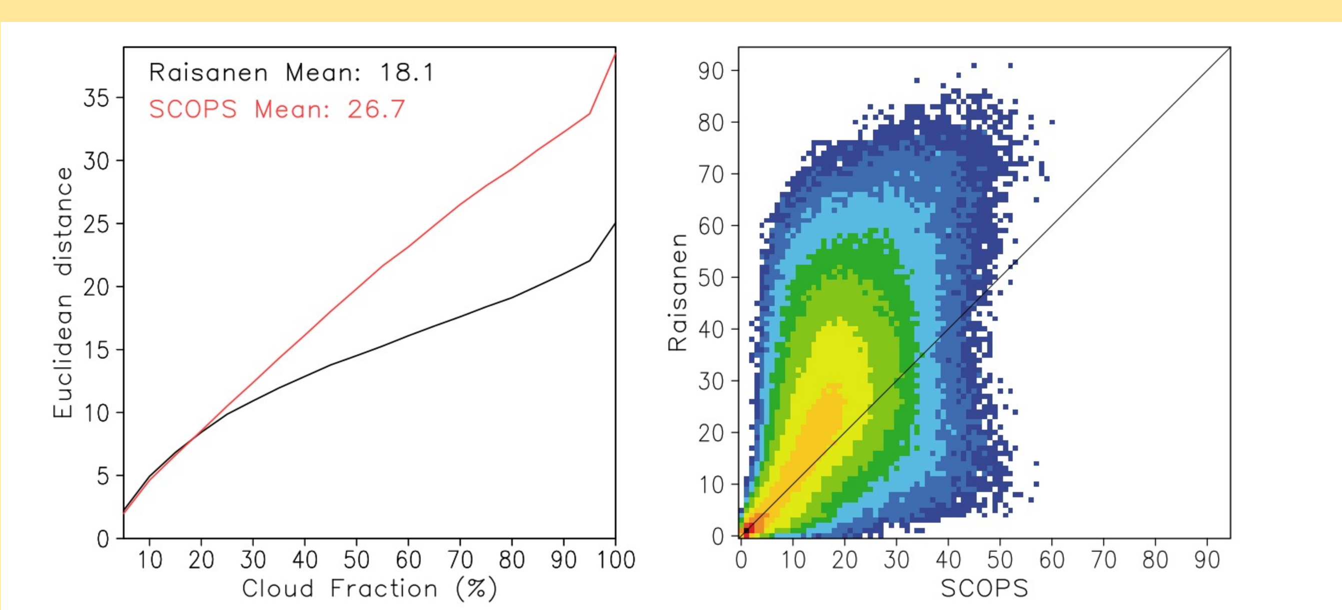
The global ocean joint histogram comparison can be refined by taking into account the MODIS Cloud Regime (Cho et al. 2021) coinciding with the 100-subcolumn scene. ***Both generators are capable of closely reproducing on average the mean CF of each CR, but again with a systematic underestimation*** (worst for CR3). ***The Raisanen generator performs overall better***, as it gives lower EDs for 8 out of 11 CRs. However, Raisanen is notably inferior for CR8 even though it reproduces the mean CF of this CR quite well. CR8 along with CR9 appear to go against Raisanen's trend of optical thin cloud underestimation; on the other hand, SCOPS's underestimation of optically thin cloud is persistent across all CRs.

Global Cloud Radiative Effect (CRE)



The bin CF errors (panels (e) and (f) on the left) ***can be converted to SW and LW CRE errors by multiplying with pseudo-Cloud Radiative Kernels*** (CRKs) calculated for the 2007 global oceans from the monthly version of the new CERES FluxByCldTyp product (Sun et al. 2021). Global SW CRE errors (panel top) are larger for SCOPS (2.7 Wm^{-2}) than for Raisanen (1.9 Wm^{-2}) , but the LW CRE errors about the same (~0.5 Wm^{-2}). ***The distribution of SW CRE errors (colors) broadly tracks the distribution of CF errors***, except for the radiatively inconsequential optically thin clouds. Binned LW CRE errors outside the ±0.15 Wm^{-2} are sporadic occur mainly for high clouds.

Performance at individual scene level



EDs of simulated joint histograms from their observational counterparts can also be calculated for individual 100-subcolumn scenes. When plotted as a function of scene CF the average ***EDs of the Raisanen generator remain consistently below those from the SCOPS*** generator above CF≈20%. The density plot of EDs from the two generators shows a much larger population above the diagonal (where SCOPS ED exceeds Raisanen ED).

The bottom line

Both generators tend to underestimate optically thin clouds and overestimate some cloud types of moderate and high optical thickness, but one of them (Raisanen) clearly produces cloud fields closer to observations. Associated radiative flux errors can be as high as 3 Wm^{-2} in the SW part of the spectrum.

References

1. Bodas-Salcedo, A., et al., 2011: COSP: Satellite simulation software for model assessment. BAMS, 92 (8), doi:10.1175/2011BAMS2856.1.
2. Cho, N., J. Tan, and L. Oreopoulos, 2021: Classifying Planetary Cloudiness with an Updated Set of MODIS Cloud Regimes, JAMC, 60(7), 981-997, https://doi.org/10.1175/JAMC-D-20-0247.1.
3. Räisänen, P., Barker, H. W., Khairoutdinov, M., Li, J., & Randall, D. (2004). Stochastic generation of subgrid-scale cloudy columns for large-scale models. QJRMS, 130, 2047–2068.
4. Sun, M, D. R. Doelling, N. G. Loeb, R. C. Scott, J. Wilkins, L. Nguyen, and P. Mlynczak, 2021: Clouds and the Earth's Radiant Energy System (CERES) FluxByCldTyp Edition 4 Data Product, JTECH, in review.