Estimating the Regional Bias of MODIS-retrieved Liquid Cloud Droplet Effective Radius through MISR-MODIS Data Fusion

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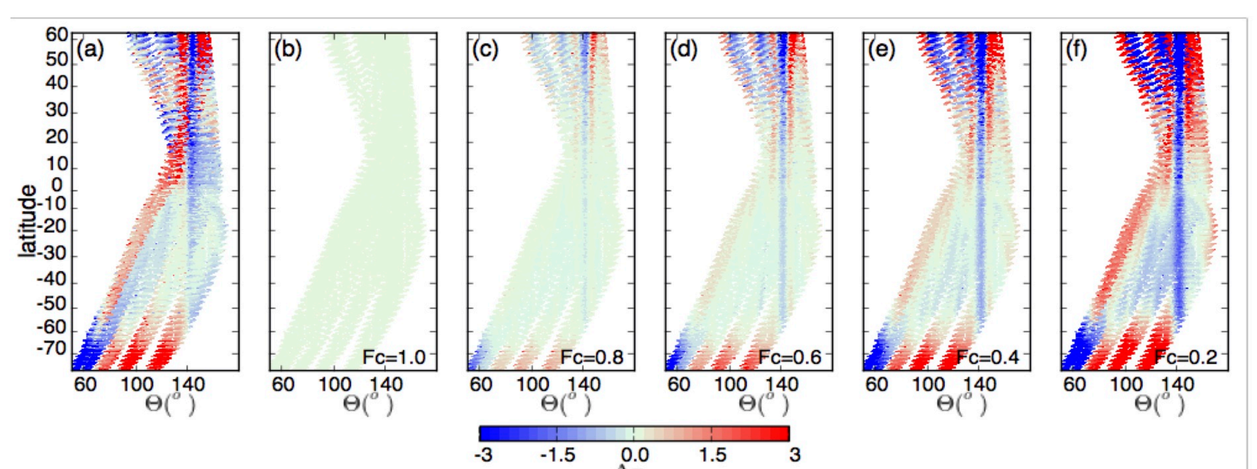
Introduction

The **effective radius (*Re*)** of the cloud drop size distribution is one of the Essential Climate Variables of the Global Climate Observing System and plays an important role in energy and water cycles of the Earth. *Re* is retrieved from the **Moderate Resolution Imaging Spectroradiometer** (MODIS) based on a bi-spectral technique [*Nakajima and King*, 1990] that makes a wide range of assumptions, **including 1-D radiative transfer**, single-mode drop size distribution, and **cloud horizontal and vertical homogeneity**. Deviations from these assumptions in nature lead to bias in the retrieved *Re*. Recently, an effort to characterize the bias in MODIS-retrieved *Re* through MISR-MODIS data fusion revealed zonal mean biases that varied from 2 to 11 μm, depending on latitude [*Liang et al.,* 2015]. Here, in a push towards bias-correction of MODIS-retrieved *Re*, we further examine the bias with MISR-MODIS data fusion as it relates to other observed cloud properties, such as cloud horizontal heterogeneity, cloud optical depth, sun-view geometry, etc., and provide a bias-correction approach for MODIS-retrieved *Re* at regional scales.

Background

Through MISR and MODIS data fusion, *Liang et al*. [2015] estimated the zonal mean MODIS-retrieved *Re* bias according to the magnitude of the "rainbow dip" in the MISR cloud optical depth observations: by applying a *Fc* correction factor defined as $Re_{2.1True} = Fc\ Re_{2.1}$ to the MISR observations, they can find a "rainbow dip" that best matches the original observation, and use the applied *Fc* value to estimate the MODIS-retrieved *Re* bias.



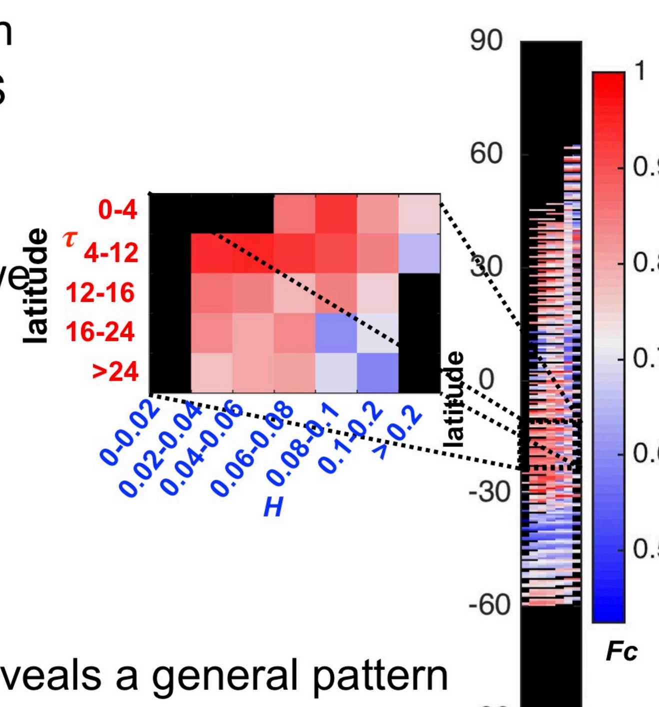
(a) Deviations from zonal mean cloud optical depth observations () from MISR Aft Cameras. (b-f) calculations with Fc intervals of 0.2. *Liang et al.* [2015]

Methodology

Following the Cloud-Element co-registration technique [*Liang et al.* 2009], MISR-MODIS Fusion data was stratified by horizontal heterogeneity (*H*) and optical depth () at a latitudinal resolution of 2.5 degrees. Here we parameterize the *Fc*-analysis to correct the MODIS *Re* at regional scales:

$$Re_{correct}(lat,lon,,H) = Fc(lat,,H)\ Re_{mean}(lat,lon,,H)$$

$$Re_{correct}(lat,lon) =$$

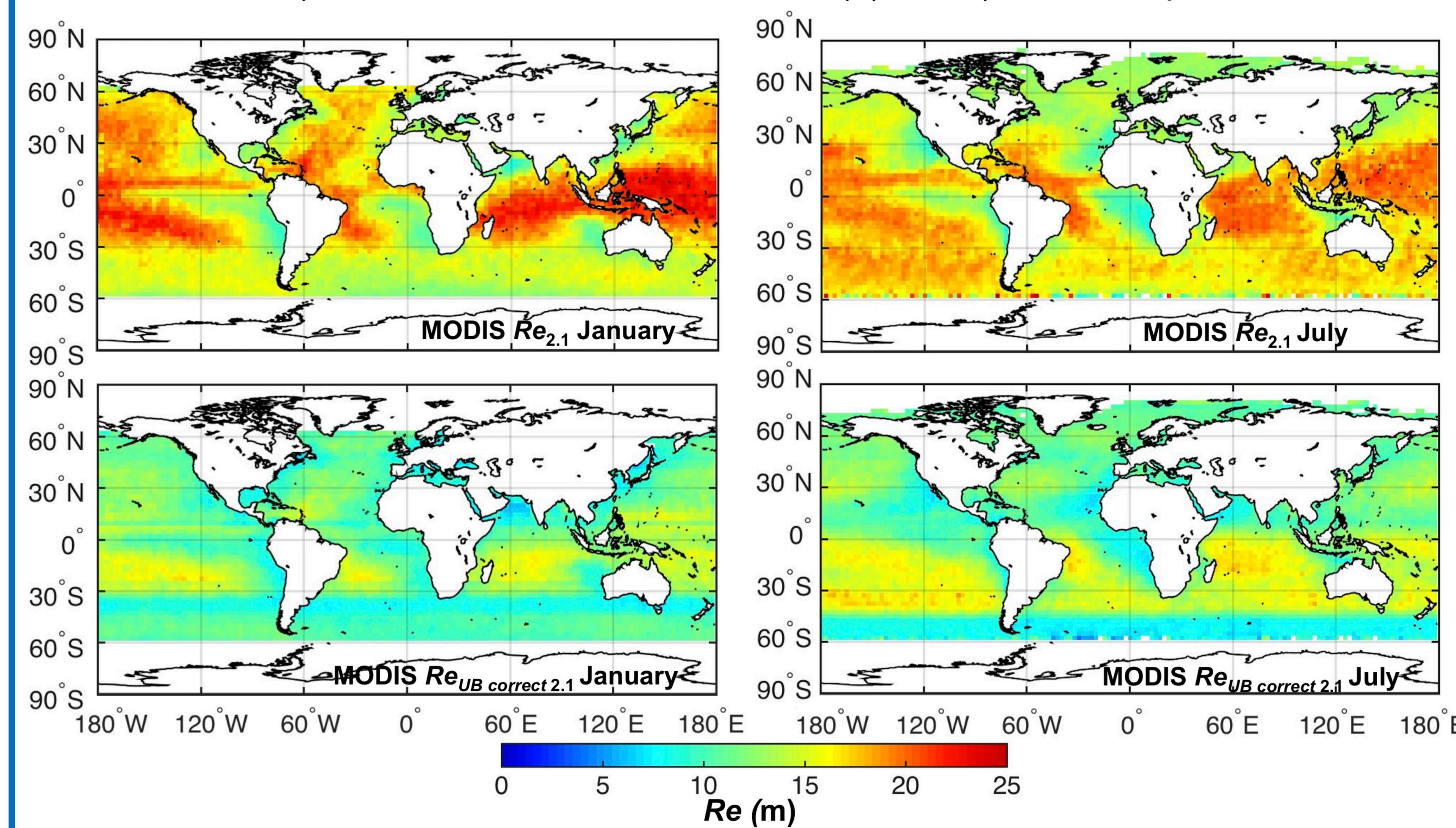


Fc correction factors in each latitude bin reveals a general pattern of larger *Fc* values for smaller *H* and bins and smaller *Fc* values for larger *H* and bins.

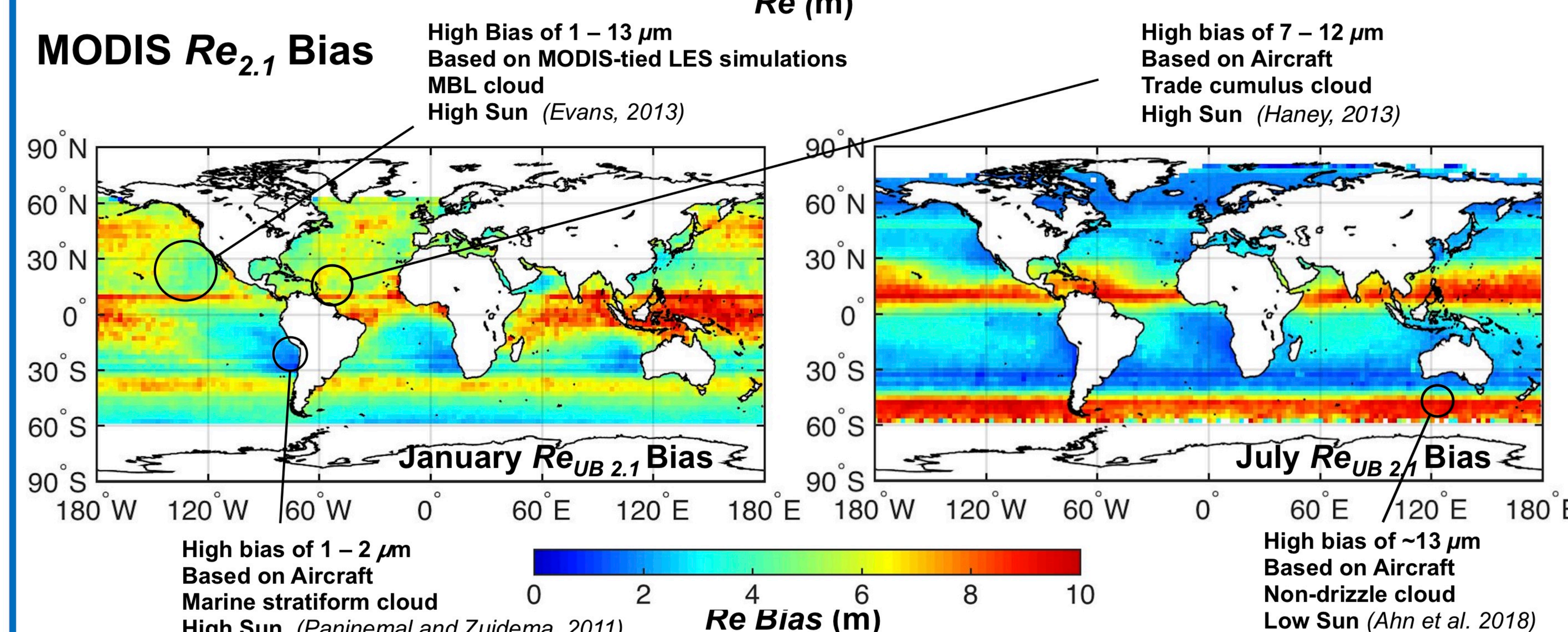
Results

Bias corrected $Re_{2.1}$ with original MODIS retrieved $Re_{2.1}$

8 year averaged January and July original MODIS-retrieved *Re* (top) with corrected *Re* upper bound estimates (minimum amount of bias-correction) (bottom) for the 2.1 μm channel.

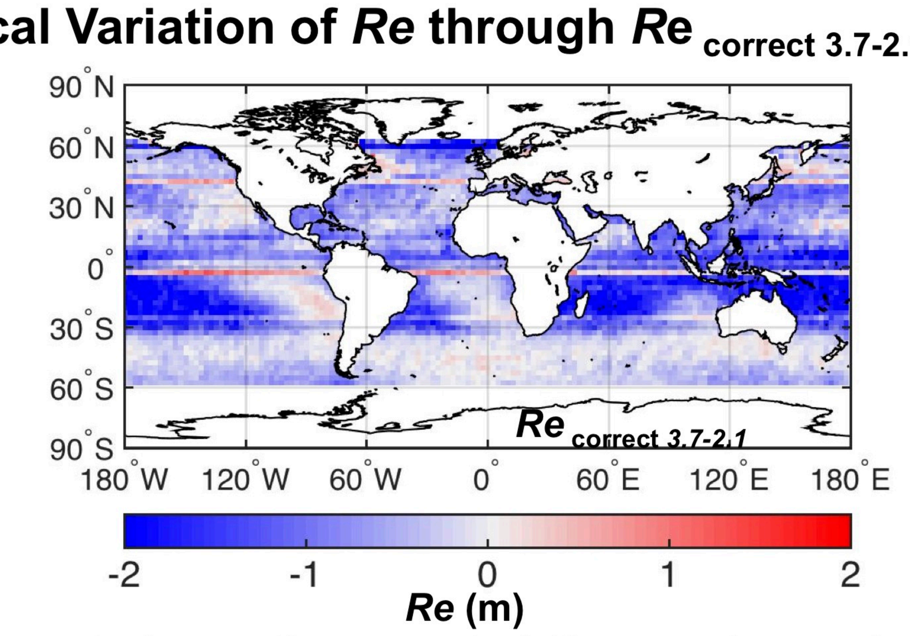


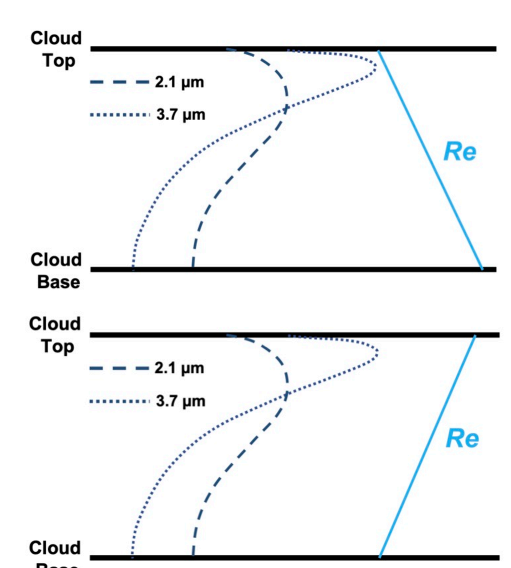
MODIS $Re_{2.1}$ Bias



Subtracting the original MODIS $Re_{2.1}$ with the corrected $Re_{2.1}$ gives an estimate of the minimum amount of $Re_{2.1}$ bias, for January and July, respectively.

Vertical Variation of *Re* through $Re_{correct\ 3.7-2.1}$



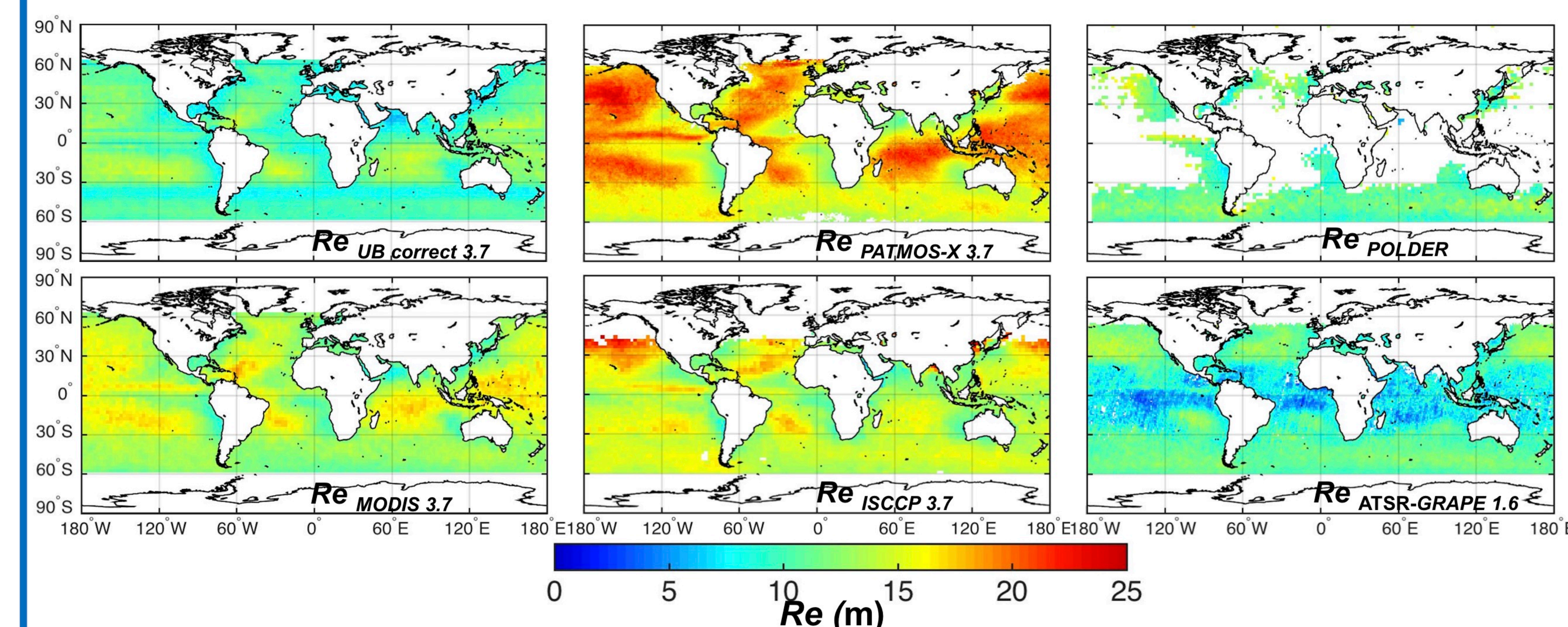


Difference between the corrected $Re_{2.1}$ and corrected $Re_{3.7}$ ($R_{e\ 3.7-2.1}$) for January tends to suggest that vertical variations of *Re* are related to cloud regimes. In general, $R_{e\ 3.7-2.1}$ are slightly positive over marine-stratocumulus regions and negative over the rest of the world.

Discussion

Comparison of various satellite retrieved *Re* products

Different satellite-retrieved *Re* products are in poor agreement with each other. When compared with other satellite retrieved *Re* products, the upper bound corrected *Re* is also different from the rest. For January, the corrected $Re_{3.7}$ mean *Re* values ranging from 5-10 μm in the coastal marine stratocumulus regions, and mean *Re* values from 12-15 μm in the cumulus regions, both are consistent with field campaign observations. The comparison also suggests that instruments which uses the bi-spectral technique (MODIS, PATMOS-x and ISCCP) appear to have larger mean *Re* values compared to instruments that rely on other retrieval techniques (POLDER, ATSR-GRAPE). However, sampling differences between these satellite products are also likely at play.



Summary

- Through data stratification, Global distributions of **bias-corrected MODIS R_e** of mean ***Re* values** from **5-15 μm for January** and **5-17 μm for July.**
- Estimated **MODIS-retrieved *Re* bias are at least ~1-10 μm** for both **January** and **July,** depending on cloud regimes; comparisons with **past field observations** appear to be **in good agreement.**
- Difference between **bias-corrected *Re*** from **different spectral channels (2.1 μm and 3.7 μm)** show **dependence on different cloud regimes,** suggesting **differences** in **vertical variations** of ***Re* profiles** between them.

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