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Cirrus cloud heterogeneity effects on MODIS-like optical property retrievals using VIS/TIR synergy

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Cirrus clouds are relevant components of the Earth's climate and radiation budget, but their role is still uncertain. Satellite imager retrievals of cirrus cloud optical thickness (COT) and ice crystal effective particle size, such as those from MODIS, primarily use solar reflectance observations from a combination of a non-absorbing visible (VIS), near infrared (NIR), or shortwave infrared (SWIR) channel and an absorbing SWIR or mid-wave infrared (MWIR) channel. Thermal infrared (TIR) retrieval techniques, such as the Split Window Technique (SWT), are also used for thin cirrus with small effective radii. For both solar and IR retrieval methods, current global operational algorithms assume that the observational pixels are independent (i.e. Independent Pixel Approximation (IPA)) and homogeneous between two planes (Plane Parallel Approximation (PPA)). The impacts on ice cloud retrievals of deviations from these approximations, such as cloud horizontal heterogeneity, are yet to be understood.

For cirrus cloud optical property retrievals, the SWT has several major advantages over solar reflectance techniques i) the SWT has demonstrated better retrieval accuracy for thin cirrus with small effective radii, and ii) horizontal heterogeneity effects in the TIR spectrum are mainly dominated by the PPA bias that primarily depends on the COT subpixel heterogeneity; for solar reflectance channels, on the other hand, in addition to the PPA bias, the IPA can lead to significant retrieval errors due to a larger photon horizontal transport between cloudy columns, as well as brightening and shadowing effects that are more difficult to quantify.

We present a strategy to improve MODIS TIR retrievals of cirrus cloud optical properties by accounting for sub-pixel cloud horizontal heterogeneity effects at the MODIS TIR spatial resolution of 1-km. Heterogeneity effects are inferred from high resolution COT retrievals using the 250-m and 500-m MODIS VIS, NIR, and SWIR channels. Heterogeneity effects in the TIR are evaluated as a function of spatial resolution in order to estimate the optimal spatial resolution for TIR retrieval applications. In addition, heterogeneity effects in the VIS/NIR/SWIR and TIR are compared to estimate their impact on cloud products retrieved using a combination of both retrieval methods. The impact of the horizontal cloud heterogeneity on the thermal correction of the 3.75μm MWIR channel will be also studied. These investigations are performed using a cirrus 3D cloud generator (3DCloud), a 3D radiative transfer code (3DMCPOL), and two retrieval algorithms, namely the operational MODIS retrieval algorithm (MOD06) and a research-level SWT algorithm.