



Evaluating Climate-Scale Stability of Reflected Solar Satellite Cloud Retrievals

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Introduction

Are domain-aggregated, long-term climate trends in retrieved reflected solar cloud properties detectable despite instrument-related and algorithm-related aliasing errors?

Potential Instrument-Related Aliasing Contributions

Science Question: By how much do changes in instrument calibration distort reflected solar cloud property decadal trends?

Objective: Quantify how changes in calibration error feed into cloud property changes.

Science Question: By how much do reflected solar cloud property retrieval assumptions distort trends in retrieved cloud properties?

Objective: Quantify how the plane-parallel assumption in reflected solar satellite cloud retrievals distorts cloud optical thickness decadal trends by determining how and if the large-scale 3D optical thickness bias changes over time.

- The three panel procedure below will be performed for each time (month), (zonal) region, set of solar and viewing geometries.

Study Assumptions (and opportunities for future work)

- Same instrument model with same wavelength bands used over time
- Same retrieval algorithm used between two decades
- Extension for future work: Conduct similar studies, but also investigate impact of changing instruments and algorithms

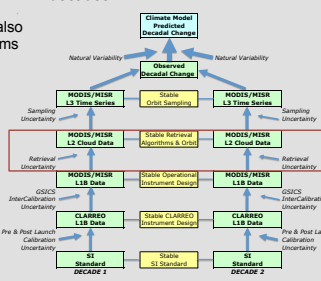
Reflected Solar (0.4 μm – 2.5 μm) Cloud Properties

- Cloud Optical Thickness
- Effective Particle Size
- Thermodynamic Phase
- Cloud Fraction
- Liquid or Ice Water Path

Potential Algorithm-Related Aliasing Contributions

- CERES instruments are capable of calculating the SW Cloud Radiative Effect (CRE) directly from broadband radiative fluxes using the 3D anisotropy by cloud type within its Angular Distribution Models and measurements made using its rotating azimuth plane scan [Loeb et al., 2005].
- However, we still need to understand the role of cloud properties (e.g. cloud fraction, optical thickness, particle size, cloud type) in SW CRE changes.
- Future studies will investigate other assumptions and their impacts on other cloud properties.

Traceability of uncertainty in decadal change in cloud properties between two decades.



In these studies, we will be focusing on evaluating the stability and uncertainty of Level-2 Cloud Retrieval algorithms over climate scales (zonal/global and monthly/annual).

Instrument Calibration and Cloud Property Trends

Objective 1: Test the impact of changes in instrument calibration gain, offset, and linearity on reflected solar retrieved cloud optical properties to quantify the potential impact of instrument calibration on multi-decadal cloud property trends.

- How does instrument calibration error impede our ability to isolate cloud property trends?
- By how much do such changes increase the time to detect trends?

Method

- Impose absolute error changes to reflectance data and run modified data through retrieval algorithms (e.g. MODIS or CERES-MODIS). How do the retrieved cloud properties change?
- Using the CERES Cloud Property Retrieval System
- These imposed changes simulate potential decadal instrument changes.

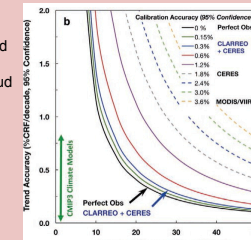
Accuracy Uncertainty Factor

$$U_a = (1 + \frac{\sigma_{cal}^2 \tau_{cal}^2}{\sigma_{var}^2 \tau_{var}^2})^{1/2}$$

Time to Detect Uncertainty Factor

$$U_t = (1 + \frac{\sigma_{cal}^2 \tau_{cal}^2}{\sigma_{var}^2 \tau_{var}^2})^{1/3}$$

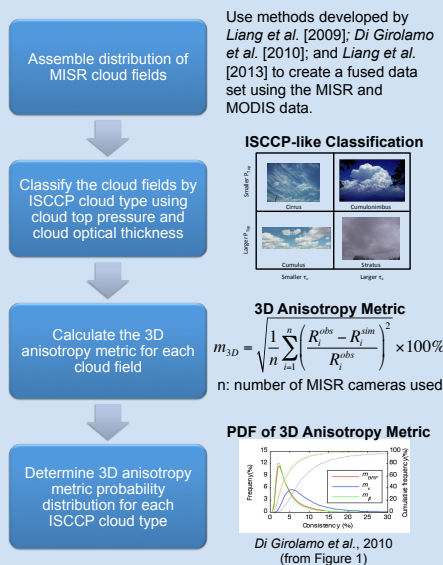
We can use the two factors to the left to quantify by how much changes in instrument calibration impact our ability to detect trends in various geophysical variables [Wielicki et al., 2013].



Illustrates large impact of absolute calibration accuracy on time to detect trends and climate trend accuracy in Cloud Radiative Forcing [Wielicki et al., 2013].

Measurement-Based Study

Objective: Collect an assortment of collocated MISR and MODIS-measured cloud fields distributed by location, time of year, and solar and viewing geometries to calculate realistic PDFs of 3D anisotropy metric for different cloud types.

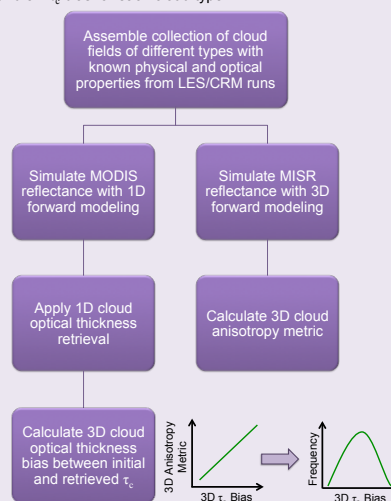


Measurement Study Outputs

- Probability distributions of 3D anisotropy metric, comparable to Di Girolamo et al., [2010] figure above, but for each ISCCP cloud type.

3D Radiative Transfer-Based Study

Objective: Using dynamically simulated cloud fields representative of the distribution of ISCCP cloud types as input to a 3D radiative transfer model, determine the relationship between 3D anisotropy metric and 3D τ_c bias for each cloud type.

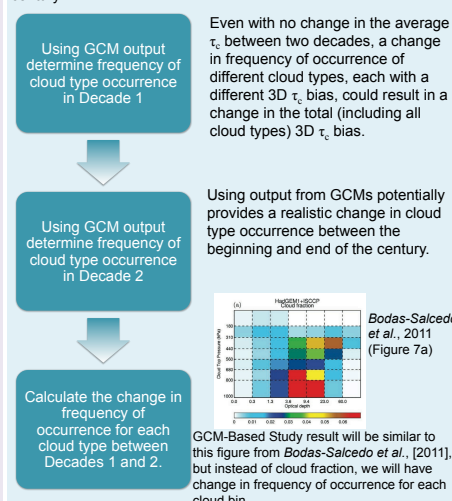


Radiative Transfer Study Outputs

- Establish relationship between 3D τ_c bias & 3D anisotropy metric for each ISCCP cloud type.
- Use this relationship and the PDFs of 3D cloud anisotropy metric (from Measurement Study) together to determine realistic frequency distribution of 3D τ_c bias for each ISCCP cloud type.

GCM Output-Based Study

Objective: Using CMIP5/CFMIP model output, determine the change in the frequency of occurrence of each ISCCP cloud type between two decades, each at the beginning and end of the 21st century.



GCM-Based Study Outputs

- Using the output from the RT and Measurement studies, map the determined realistic frequency distribution 3D τ_c bias to GCM change in frequency of occurrence for each cloud type.
- Calculate the change in total (for all cloud types) 3D τ_c bias between two decades. Does this differ from zero?

Benefit to MISR and Remote Sensing Community

- Potential interest in this application of the MISR data and MISR measurement technique.
- MISR data set and many others have exceeded a decade in length. It is therefore important to investigate if current instantaneous cloud retrieval algorithms should be used to study climate scale trends.
- These studies begin to quantify any potential aliasing errors introduced by various instrument- and algorithm-based contributions.
- Such discoveries may motivate the development and rigorous testing of newly developed climate-specific cloud retrieval algorithms.

Benefit to Climate Science Community

- Quantifying amount by which the PP assumption may alias into the τ_c trend will provide confidence in ability of satellite observations to constrain climate model calculations of the CRE and Cloud Feedback over climate scales.

Two Potential Outcomes

- Current retrievals have needed climate-scale accuracy and stability: This would be an important discovery, as we will have verified some important aspects of the validity of using these retrievals to study climate change.
- Current retrievals do not have the accuracy and stability needed for climate studies: We will need to develop climate-specific retrievals.
 - The framework we have developed to relate the 3D τ_c bias to 3D cloud anisotropy can be used to help quantify by how much the newly developed climate-specific algorithms alias into τ_c climate trends.