# A Comparison of Cloud and Aerosol Measurements from OCO-2 and CALIPSO

**Emily Rosenthal[1], Rob Nelson[2], Heather Cronk[2], and Chris O'Dell[2]**
**Millersville University of Pennsylvania[1], Millersville, Pennsylvania**
**Colorado State University[2], Fort Collins, Colorado**
**Correspondence: ejrosent@millersville.edu**

## Introduction: What are CALIPSO and OCO-2?

- CALIPSO and OCO-2 are two satellites in the NASA Afternoon-Train
- CALIPSO measures the vertical distribution of clouds and aerosols while OCO-2 measures carbon dioxide
- OCO-2 has three spectrometers which measure different wavelengths of sunlight
- One of the spectra, the oxygen-A band ($O_2$-A Band), is used as a "cloud screener" to try and remove clouds and aerosols, which can contaminate OCO-2 measurements
- $O_2$-A band cloud-detection output can be compared to CALIPSO data in order to examine its fidelity.

## The General Idea

- If reflected sunlight hits clouds and aerosols instead of the surface, the photon path length is shortened.
- This path shortening is imprinted on the $O_2$-A band spectrum and indicates there is likely a cloud or aerosol layer present.
- We used CALIPSO measurements to validate the OCO-2 cloud screener and investigate where there is agreement and disagreement.

## Key Questions

1. Where do OCO-2 and CALIPSO agree and disagree on where there is a cloud or aerosol layer?
2. Does OCO-2 have problems detecting certain types of clouds?

## Methodology & Results

- We used ~650,000 co-located OCO-2/CALIPSO measurements from May 2015 in our analysis
- We compared the OCO-2 cloud screener to CALIPSO optical depths

### Co-located Measurements

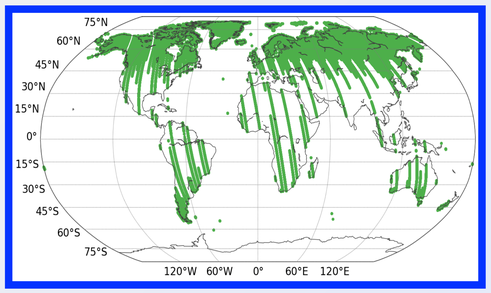
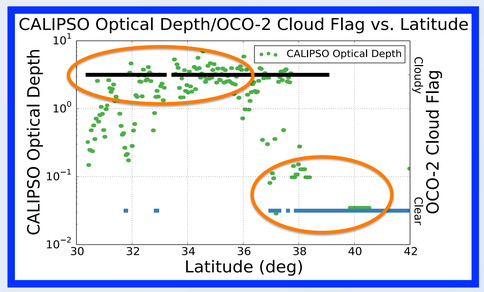



Figure 1: ~650,000 co-located OCO-2 and CALIPSO measurements within 5 km.

### Single Orbit




Both agree that it is cloudy!

Both agree that it is clear!

Figure 2:
- Where the cloud flag equals zero, OCO-2 has identified the scene as clear
- Where the cloud flag equals one, OCO-2 has identified the scene as cloudy

### CALIPSO Optical Depth

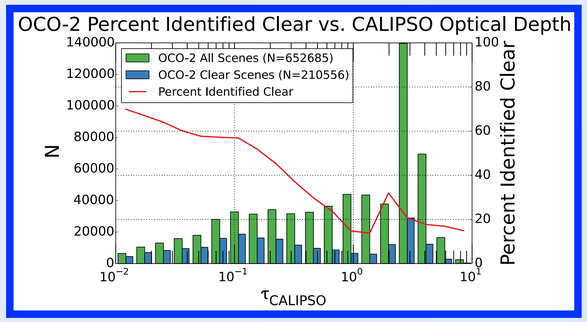



Figure 3:
- High CALIPSO optical depths indicate clouds or aerosols.
- At high optical depths the percentage of scenes OCO-2 identifies as clear is low (~20%).
- At low optical depths the percentage of scenes OCO-2 identifies as clear is high (~70%).
- This shows agreement between OCO-2 and CALIPSO.

### Previous Simulated Results

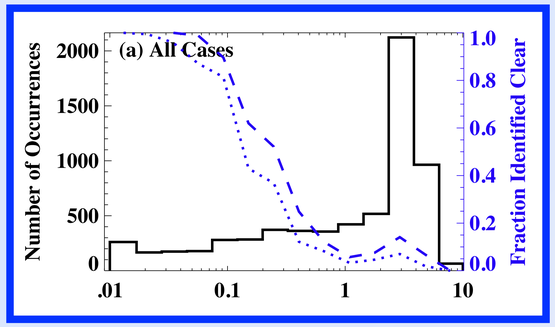



Figure 4:
- Simulations from O'Dell et al. 2012 are shown.
- This is the first time that this simulation-based result has been confirmed with real data.

### CALIPSO Cloud Top Pressure

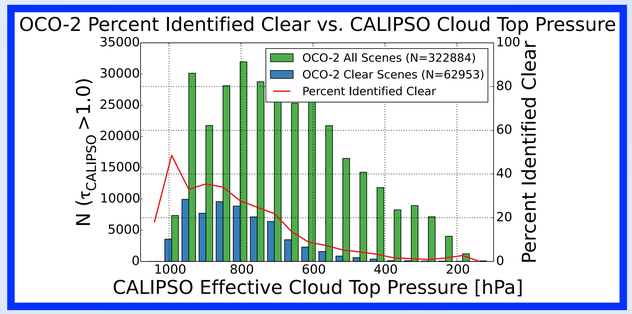



Figure 5:
- For cloudy scenes ($\tau$ >1.0), OCO-2 incorrectly thinks it is clear ~40% of the time for low clouds
- OCO-2 rarely misidentifies high clouds

## Conclusions

- Generally, OCO-2 identifies high CALIPSO optical depth scenes as cloudy and low optical depth scenes as clear.
- For cloudy CALIPSO scenes, OCO-2 correctly identifies the vast majority of high clouds.
- For cloudy CALIPSO scenes, OCO-2 misidentifies ~40% of low clouds. This confirms earlier simulation-based results for the first time with real data.
  - But… other work has shown that OCO-2 can filter out most low clouds using addition cloud information from its $CO_2$ bands.

## Future Work

- Does the performance of the OCO-2 cloud screener have a solar zenith angle dependence?
- Does OCO-2 have more difficulty with ice vs. water clouds?
- What is the optical thickness limit for high clouds that OCO-2 can detect? Theoretical studies indicate it can sense clouds with extremely low OD (< 0.05).

## References

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