A Multi-Sensor Approach to Cloud and Aerosol Detection in Support of OCO-2 XCO$_2$ Retrieval Validation

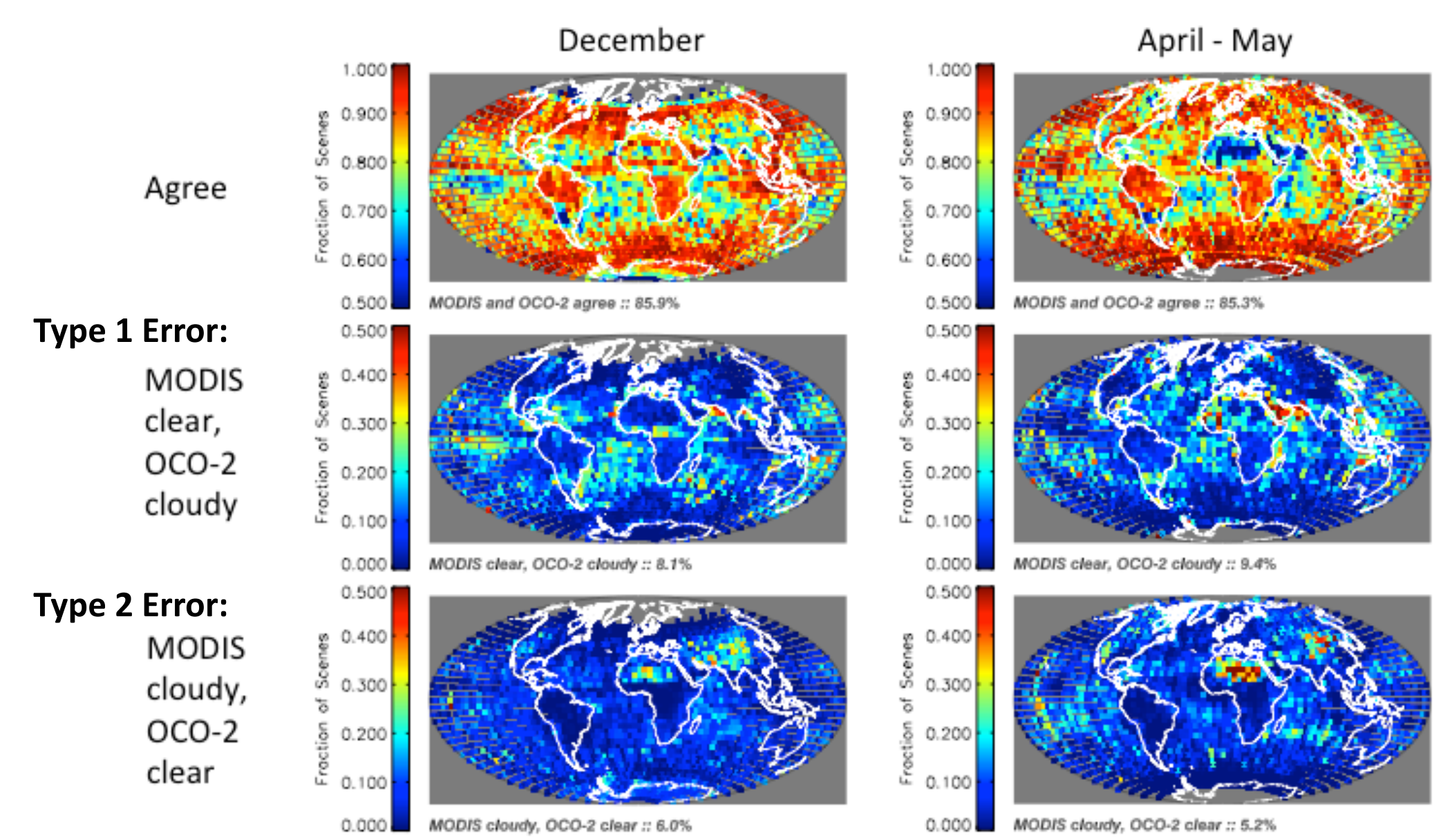Heather Q. Cronk[1], Thomas E. Taylor[1], Robert R. Nelson[2], and Christopher W. O'Dell[1]

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Introduction

The Orbiting Carbon Observatory-2 (OCO-2) satellite is the first dedicated to remote sensing of carbon dioxide. Accurate measurements of the column-averaged dry-air mole fraction of carbon dioxide (XCO$_2$) require scenes that are sufficiently clear of scattering material, making effective cloud and aerosol screening very important. The strategic placement of OCO-2 in the A-Train satellite constellation allows co-located comparisons with other instruments that have effective cloud and aerosol detection capabilities. Using a custom cloud mask developed from the MODIS 1-km cloud flag and cirrus reflectance, Taylor et al. [2016] investigated discrepancies between OCO-2 and MODIS cloud detection.
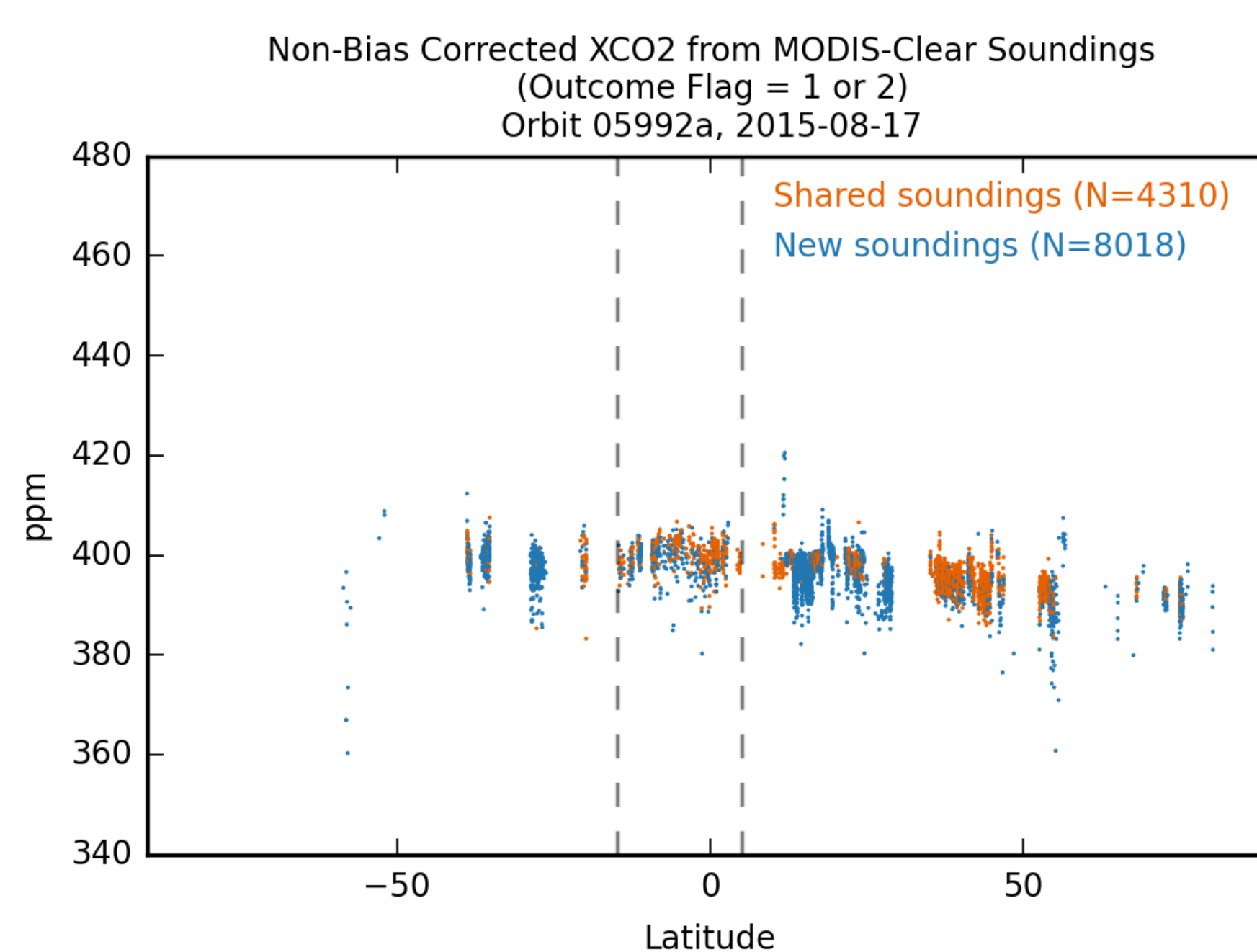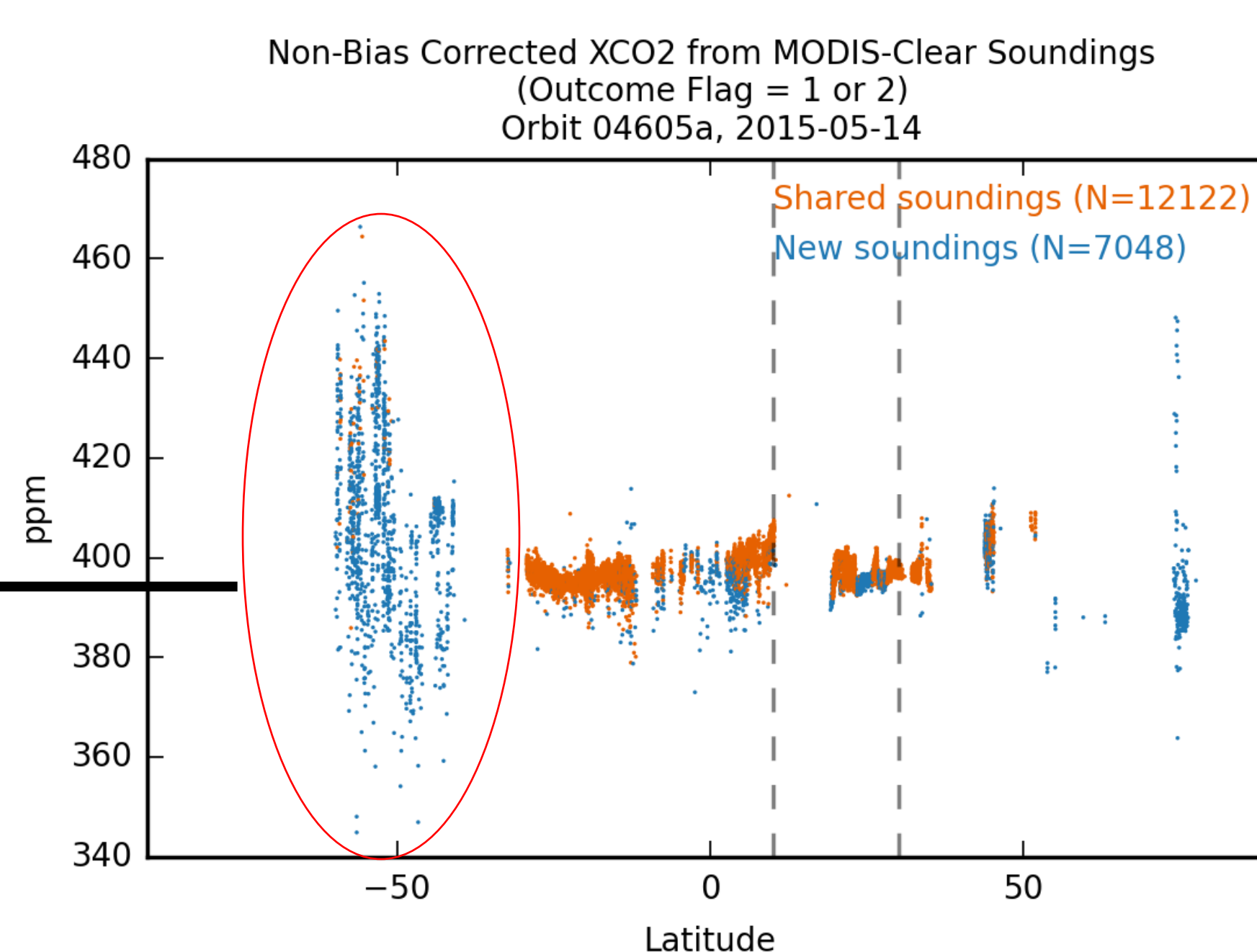
Taylor et al. 2016 (doi:10.5194/amtd-8-12663-2015)

Case Studies

1. May 14, 2015 (OCO-2 nadir orbit 04605a):

NASA Worldview (https://worldview.earthdata.nasa.gov/)
Aqua: Aqua orbital track
Yellow: CALIPSO orbital track
Red: Case study region
Imagery: Aqua-MODIS

OCO-2 Granule 04605a (Sahara)
2015-05-14

2. August 17, 2015 (OCO-2 nadir orbit 05992a):

NASA Worldview (https://worldview.earthdata.nasa.gov/)
Aqua: Aqua orbital track
Yellow: CALIPSO orbital track
Red: Case study region
Imagery: Aqua-MODIS

OCO-2 Granule 05992a (Amazon)
2015-08-17

Question 1:

For Type 1 error soundings where the OCO-2 cloud screeners identify a cloud while MODIS says it is clear, should the sounding be passed into the retrieval algorithm?
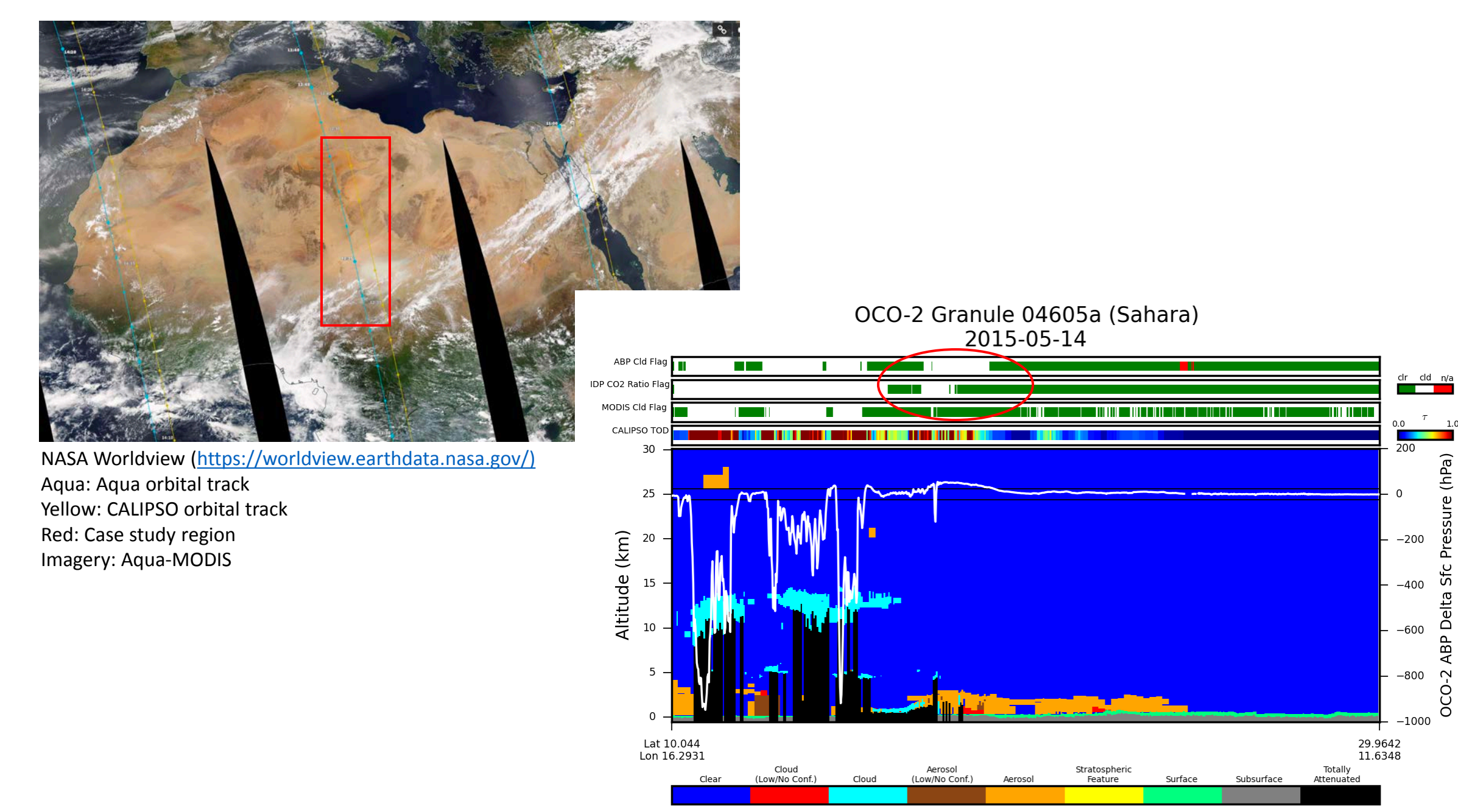
Methodology:

- Bypass initial cloud screening process and feed every OCO-2 sounding into the L2 retrieval algorithm
- Compare the operational XCO$_2$ values to those generated without the cloud pre-screeners for soundings that the Taylor et al. MODIS cloud flag marks as clear

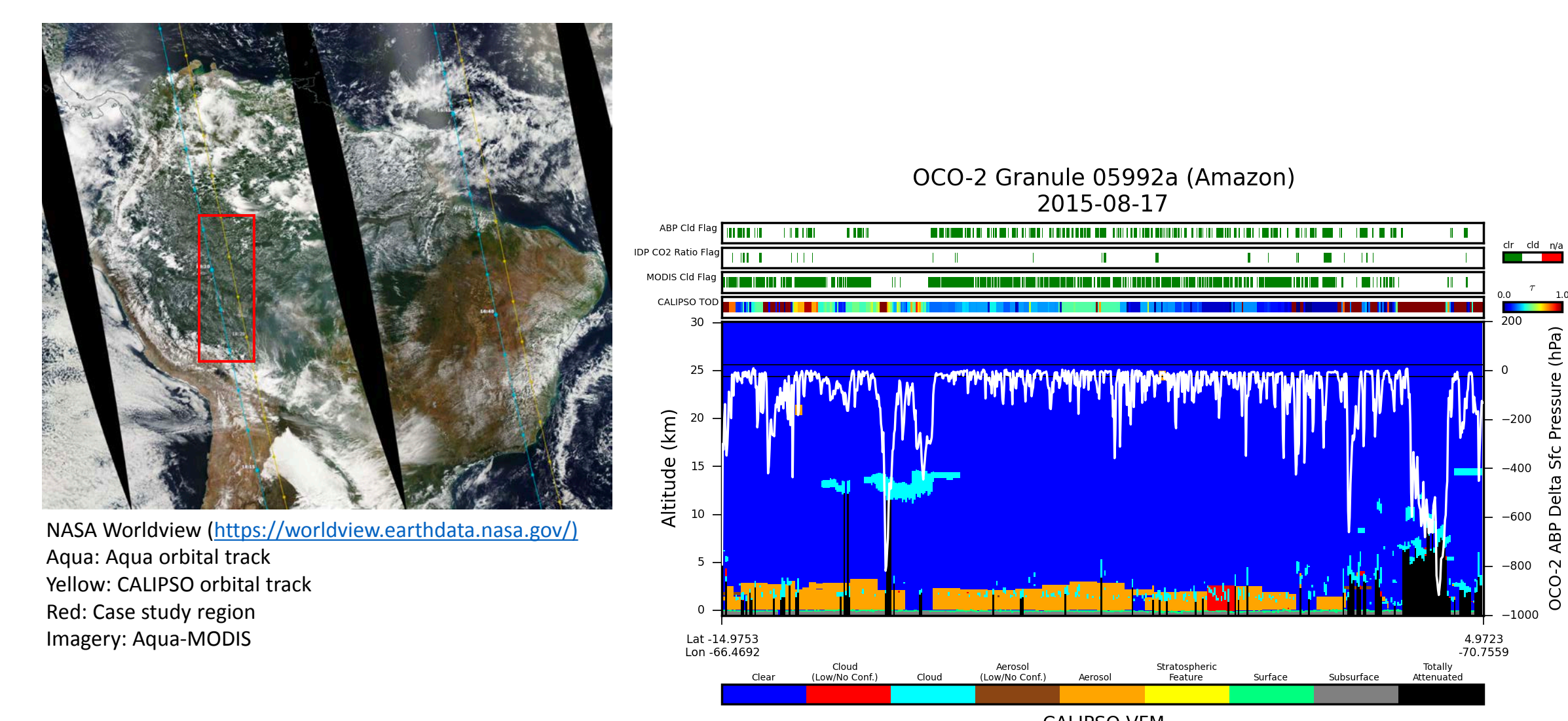*Results (focusing on case study areas between dashed lines):*

Non-Bias Corrected XCO2 from MODIS-Clear Soundings
(Outcome Flag = 1 or 2)
Orbit 04605a, 2015-05-14
Shared soundings (N=12122)
New soundings (N=7048)

Non-Bias Corrected XCO2 from MODIS-Clear Soundings
(Outcome Flag = 1 or 2)
Orbit 05992a, 2015-08-17
Shared soundings (N=4310)
New soundings (N=8018)

- Many of the reintroduced soundings do converge and produce comparable XCO$_2$ values to the surrounding operational values.
- Further analysis is necessary to determine which OCO-2 pre-screening tests removed these soundings in the operational algorithm to determine if they can be included in the future

Further investigation:

OCO-2 Granule 04605a (Southern Ocean)
2015-05-14

NASA Worldview (https://worldview.earthdata.nasa.gov/)
Aqua: Aqua orbital track
Yellow: CALIPSO orbital track
Red: Further investigation region
Imagery: Aqua-MODIS
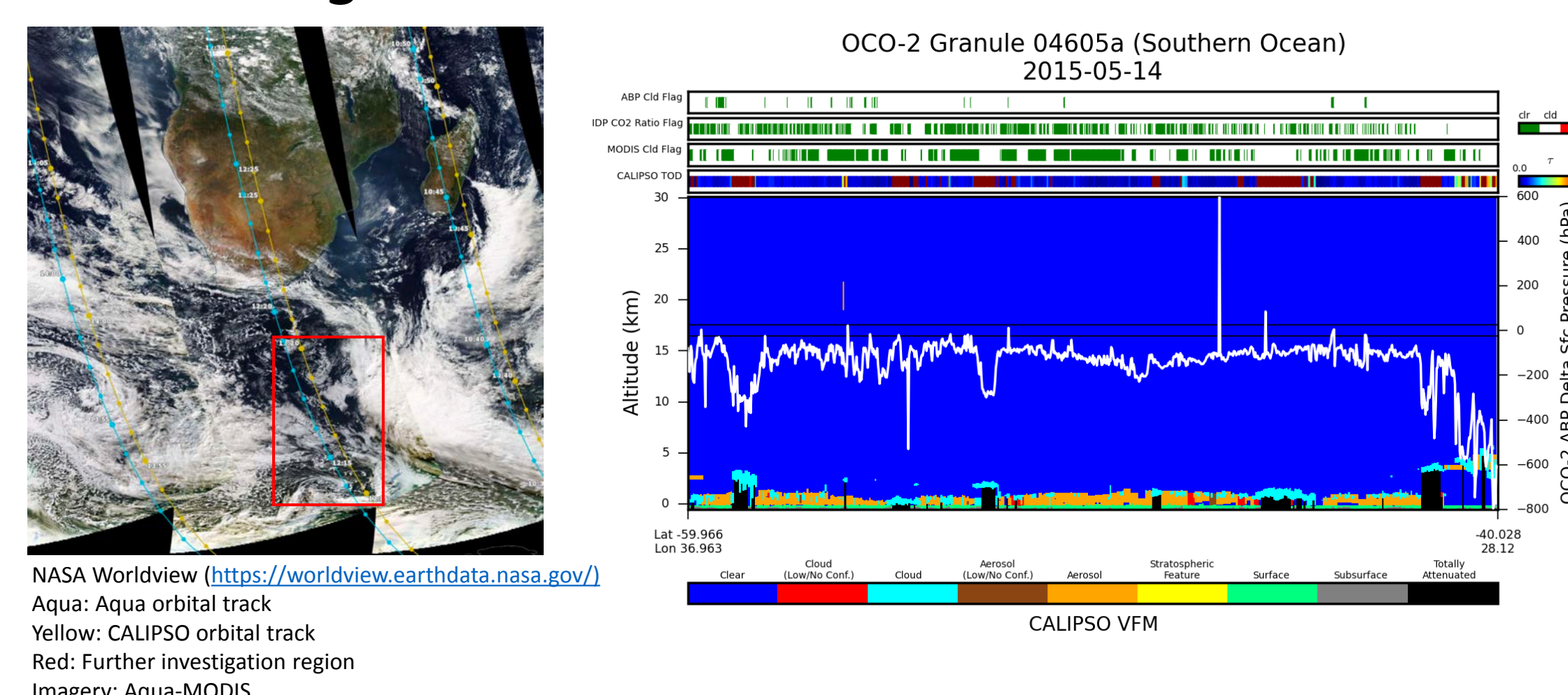
Question 2:

In cases of Type 2 error where MODIS identifies a cloud but OCO-2 identifies a clear scene, which MODIS cloud flags contribute to this conclusion?

Methodology:

- Generate a co-located OCO-2/MODIS cloud mask product (MYD35) to investigate all cloud test outcomes

Results:

Orbit 04605a (Sahara)

Orbit 05992a (Amazon)
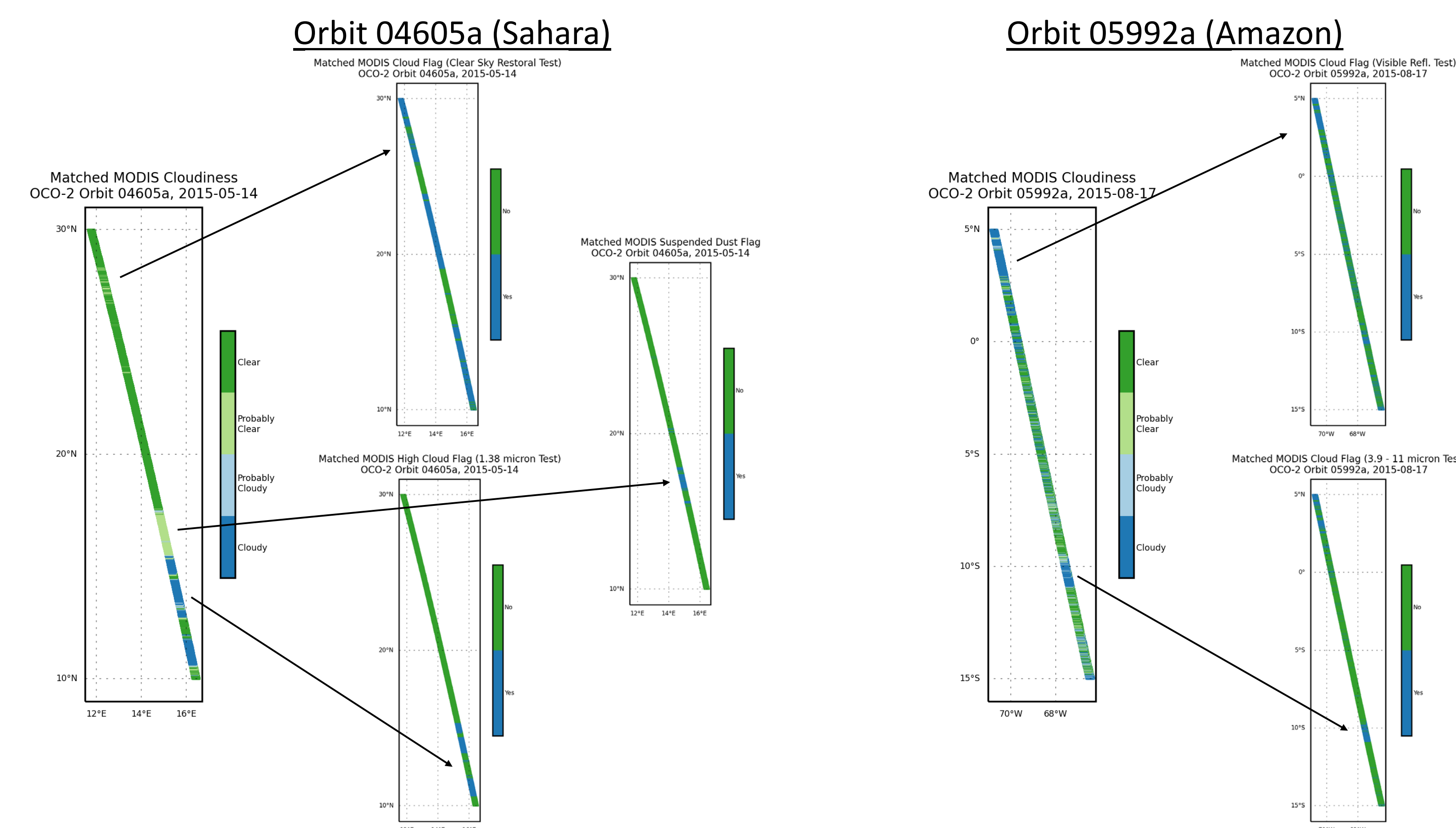
- Certain features in the MODIS cloud mask can be visually traced to a single test but most features will require additional analysis to pull apart.
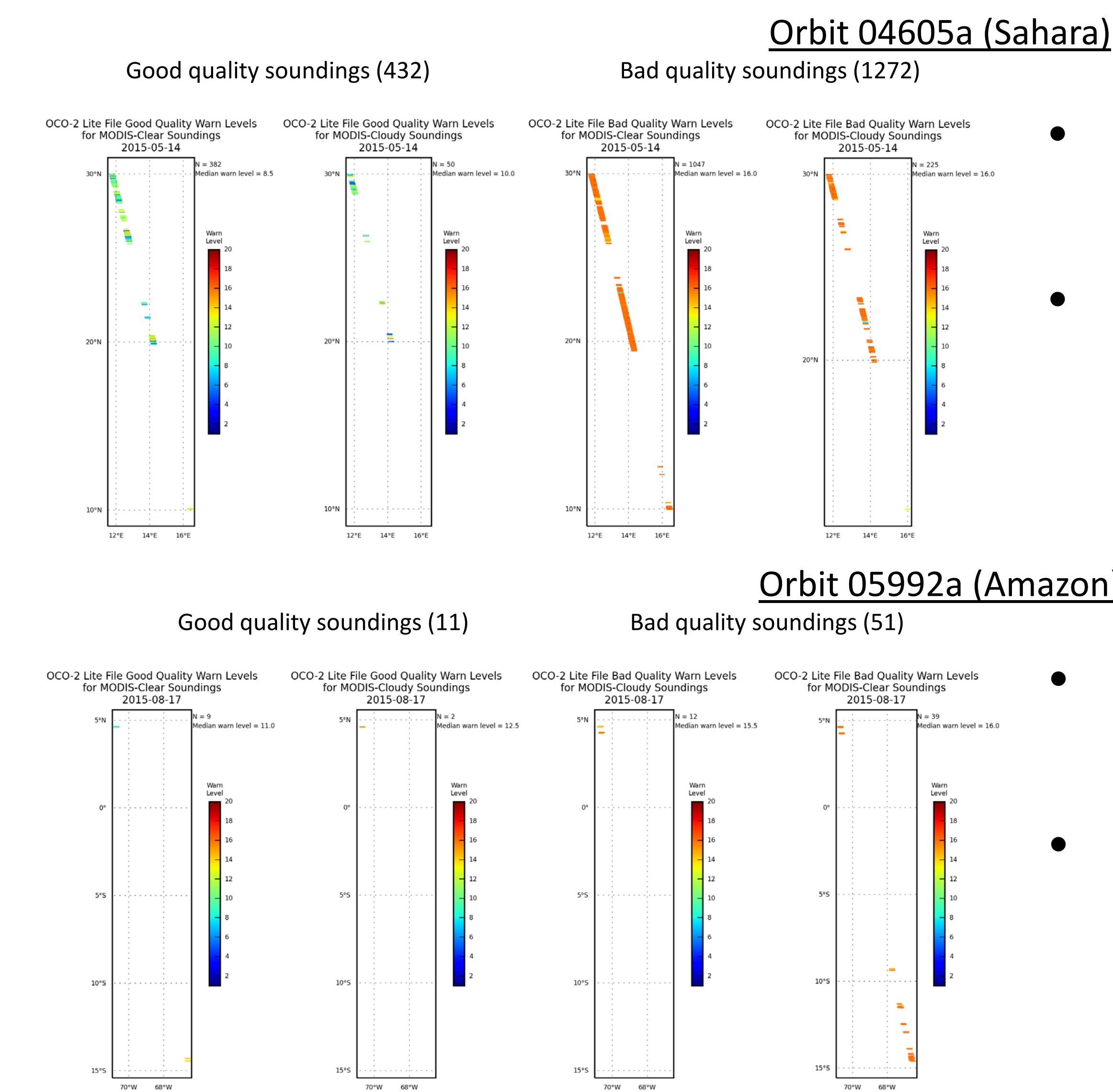
Question 3:

What is the quality of the OCO-2 XCO2 retrieval in areas of Type 2 error?

Methodology:

- Use post-processed OCO-2 Lite files to determine the quality flags and warn levels

Results:

Orbit 04605a (Sahara)
Good quality soundings (432)
Bad quality soundings (1272)

- Approximately 75% of soundings in the Lite File fail the Quality Control (QC) test
- Of the 25% that pass QC, approximately 88.4% of those are soundings that MODIS agrees are clear and 11.5% are soundings that MODIS marks as cloudy

Orbit 05992a (Amazon)
Good quality soundings (11)
Bad quality soundings (51)

- Only 62 soundings meet the criteria for inclusion in the Lite File and approximately 82% of those fail QC
- Even the 9 quality controlled soundings that OCO-2 and MODIS agree are clear have a relatively high median warn level (11)