# Cloud properties retrieved from the OCO-2 A-band spectrometer

***Mark Richardson[1], Anthony Davis[1], Heather Cronk[2], Thomas Taylor[2], James McDuffie[1], Graeme Stephens[1,2,3]***

***AGU Fall Meeting, San Francisco, California, U.S.A. 2016-12-15***

[1]Jet Propulsion Laboratory, California Institute of Technology, USA
[2]Cooperative Institute for Research in the Atmosphere, Colorado State University, USA
3Department of Meteorology, University of Reading, UK

Copyright © 2016, California Institute of Technology. All rights reserved. This work was undertaken at the Jet Propulsion Laboratory under contract with the National Aeronautics and Space Administration. Government sponsorship acknowledged. Image credit: NASA Earth Observatory

# OCO-2

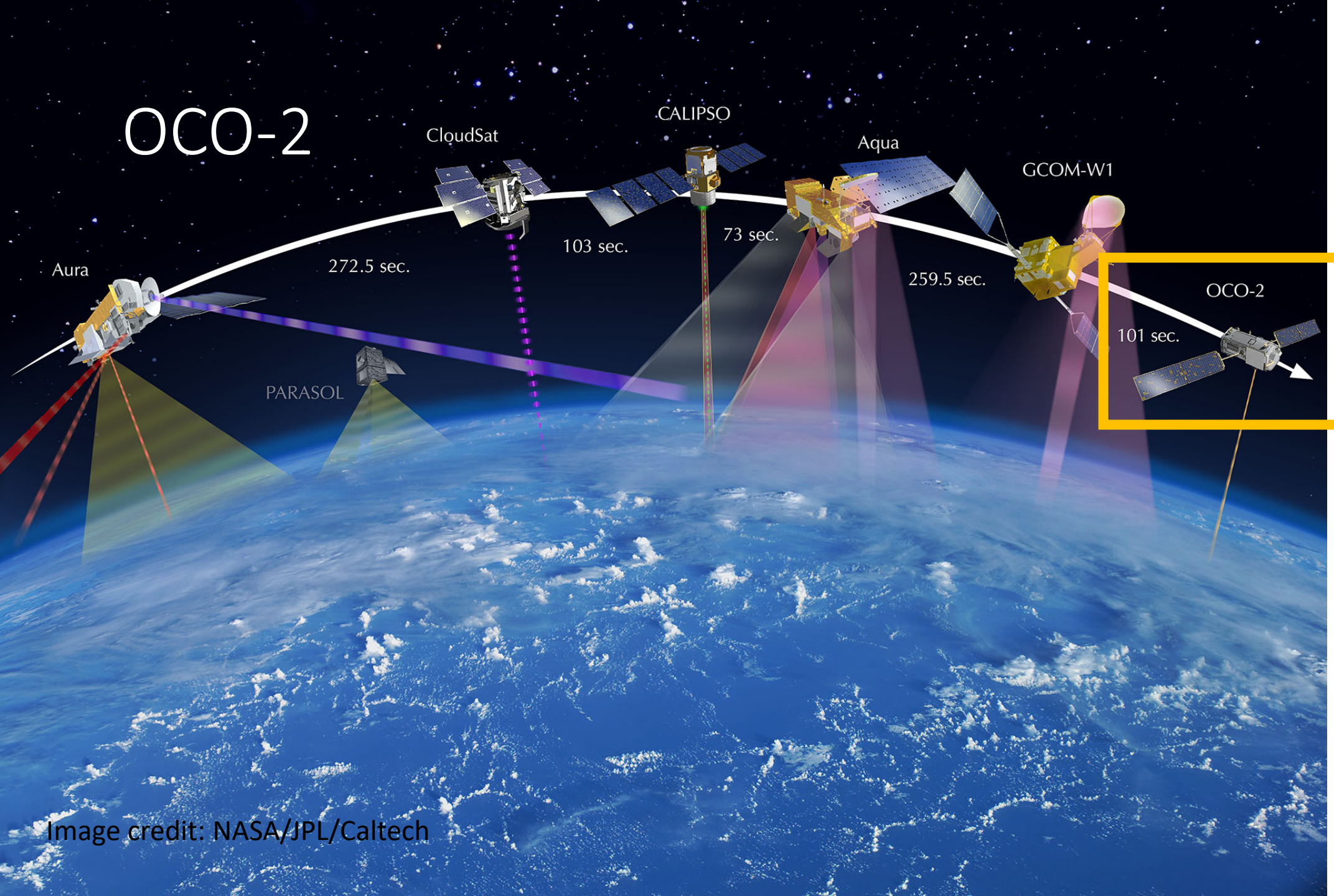
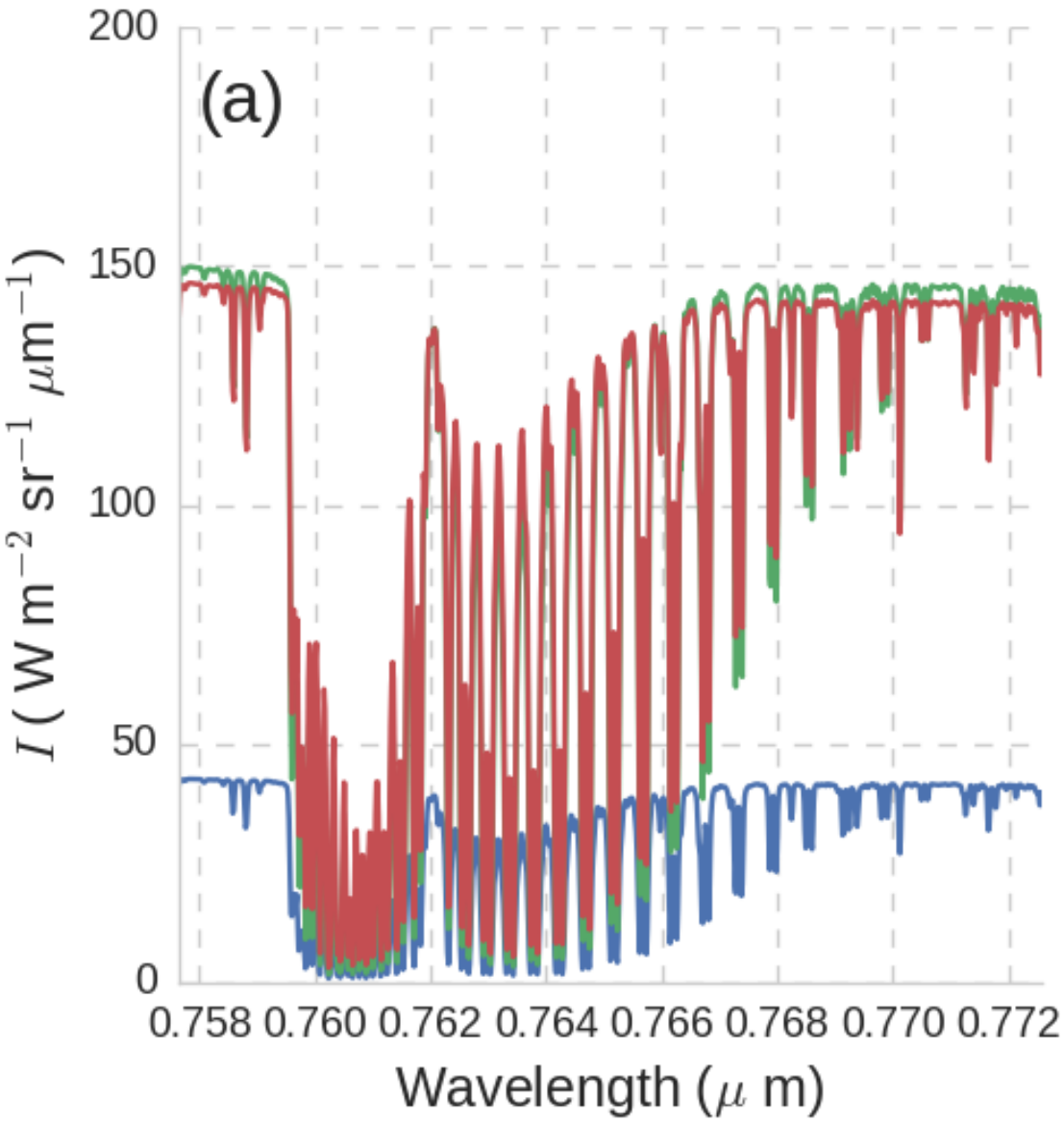


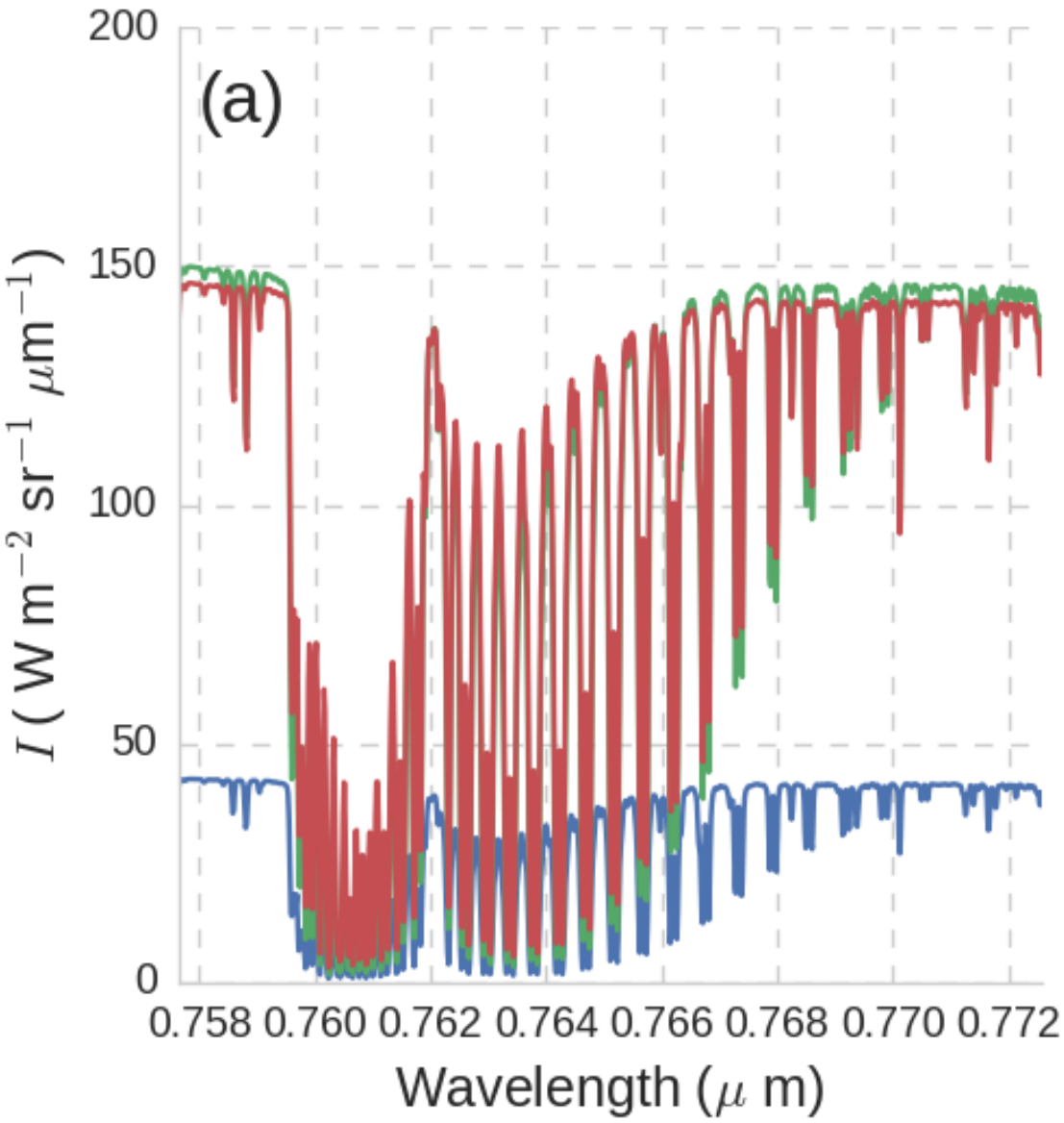

Image credit: NASA/JPL/Caltech

# (1) A-band spectra seen by OCO-2




- OCO-2 A-band FWHM $\Delta\lambda = 0.04$ nm
- Also has strong and weak CO2 bands for its day job
- We just use the CO2 channels for assigning phase (liquid/ice)

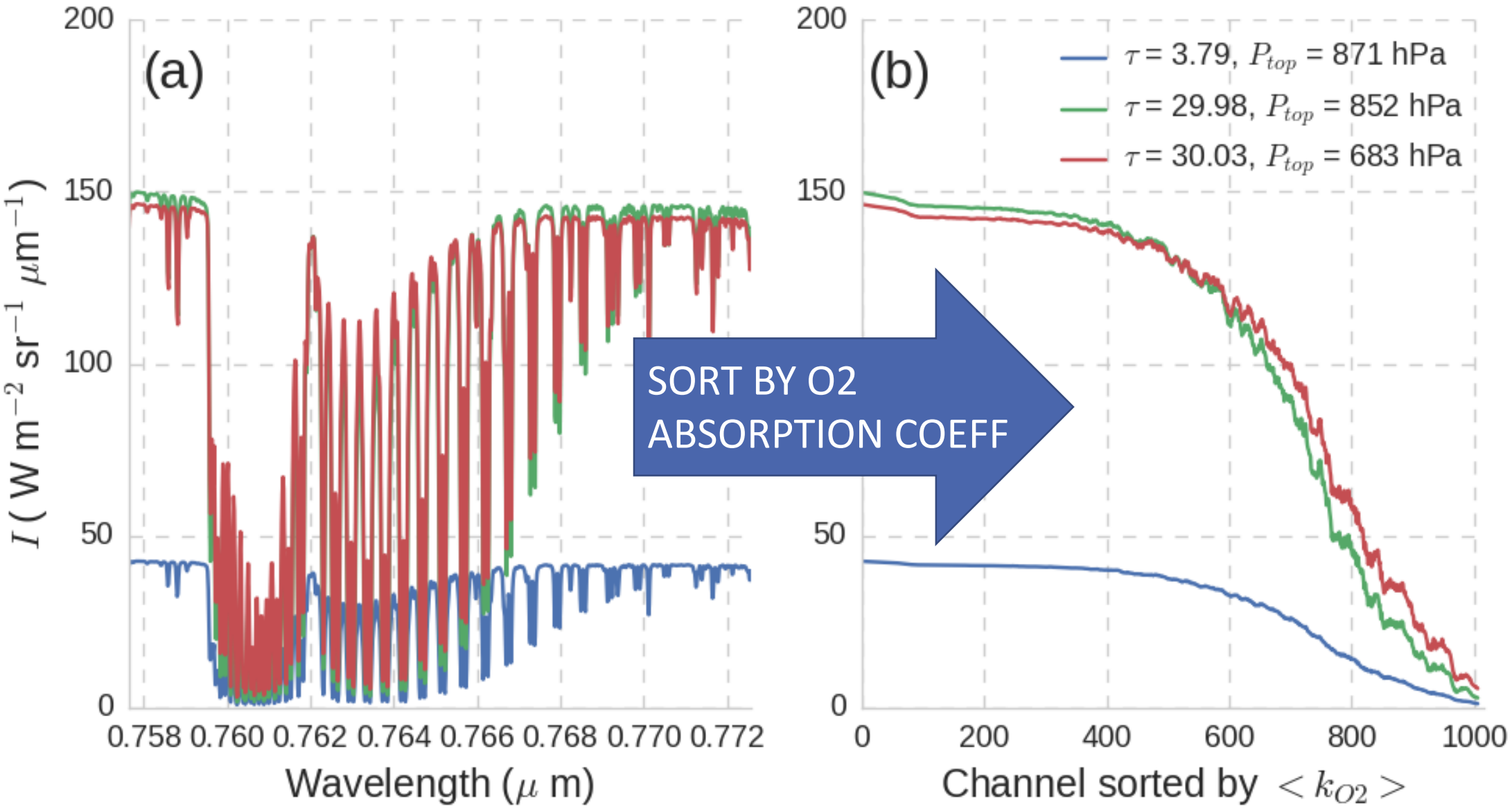
# (2) OCO-2 A-band response to clouds




Optically thick clouds are more reflective (“brighter”)

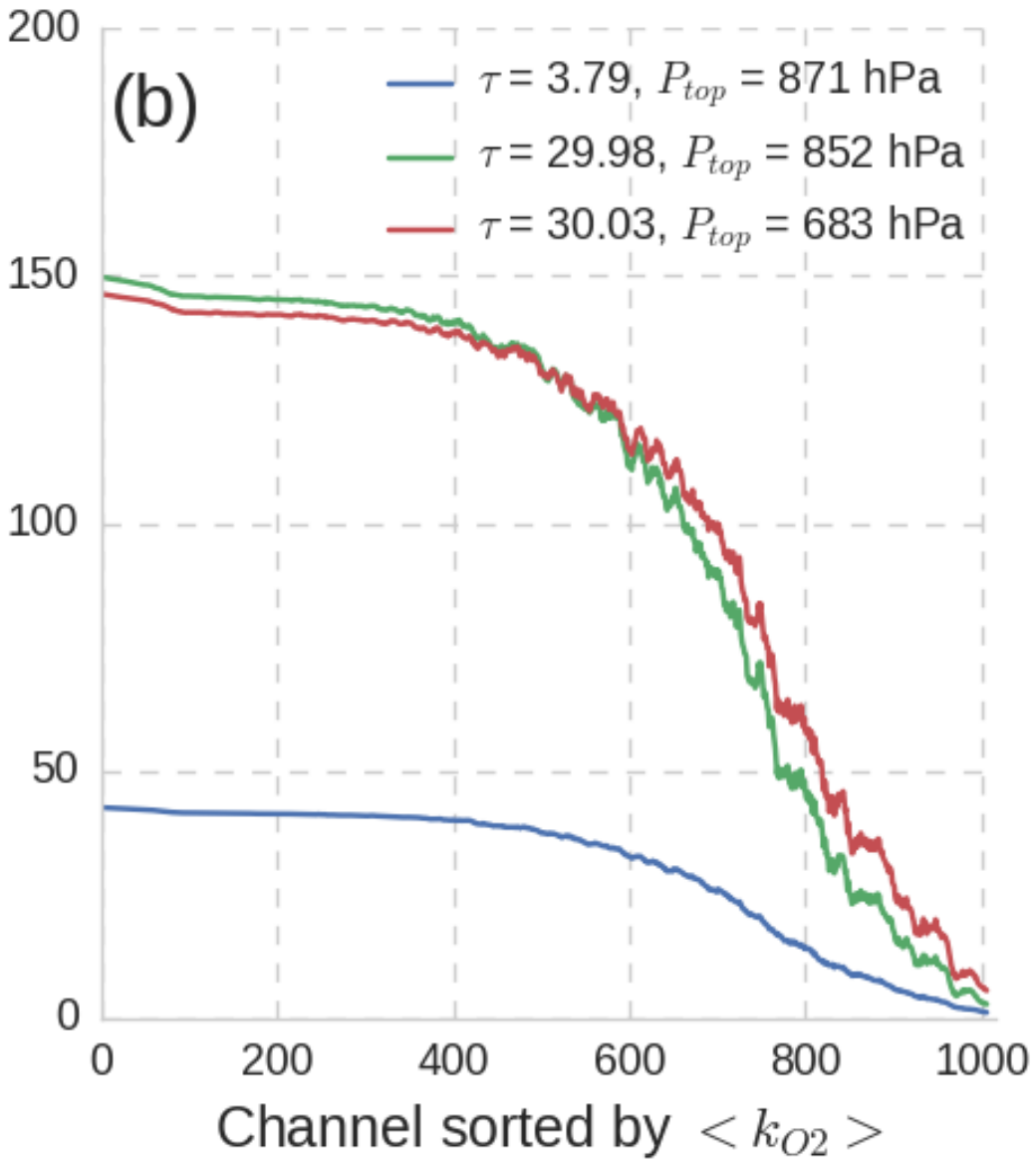
Optically thin clouds are less reflective (“darker”)

# (3) A-band spectra sorted by oxygen absorption



# (4) A-band spectra response to photon path

- The green is “darker” in the absorption bands
- Photons have travelled further → more absorption → cloud is lower and/or thicker

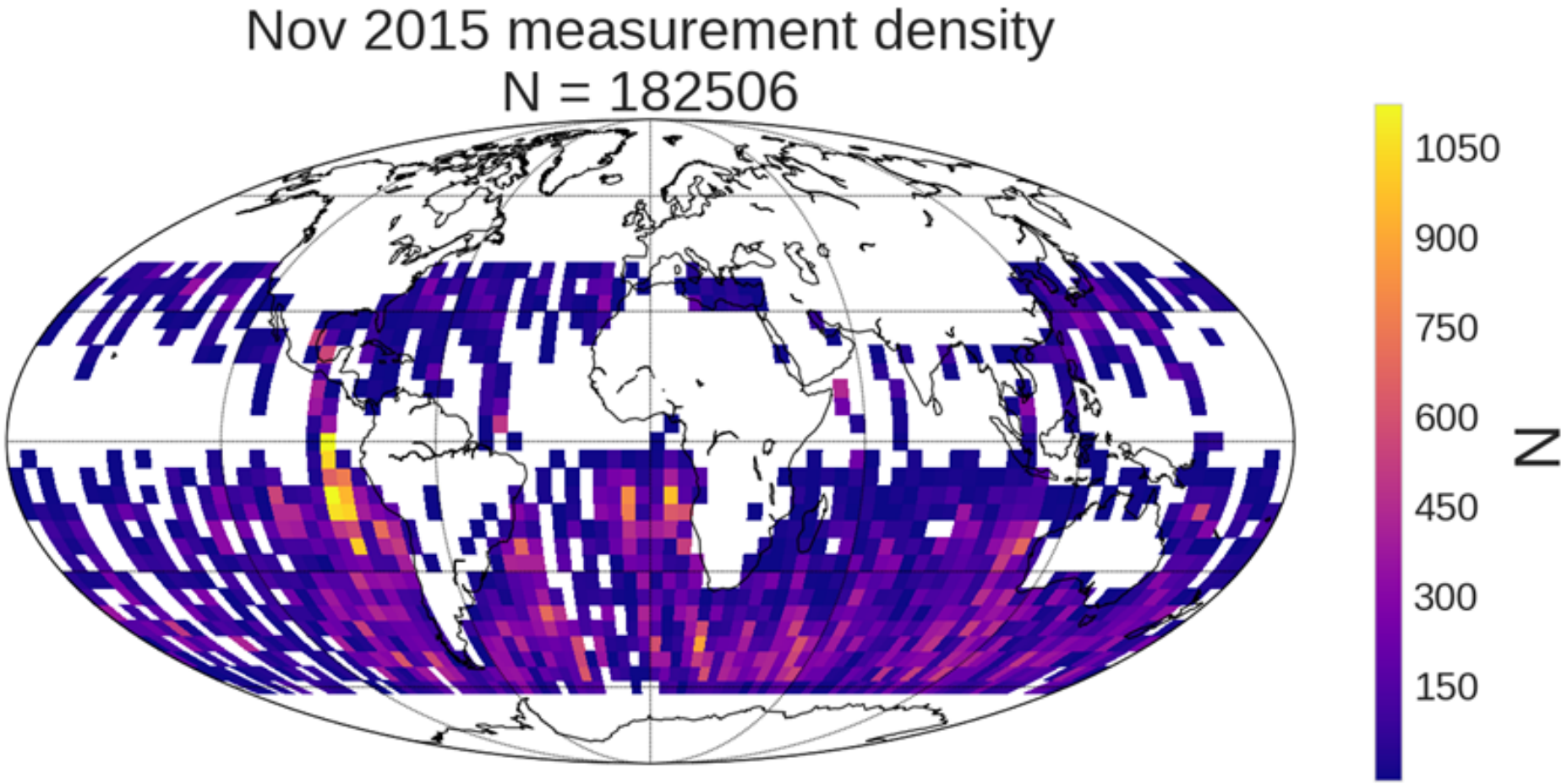


# (5) Retrieval targets

- We know the physics, let's get:
  - Phase (lookup table only, uses weak $CO_2$ band)
  - Optical depth
  - Cloud pressure thickness
  - Cloud-top pressure

# (6) November 2015 tests

- November 2015, 1-layer liquid clouds over water
- MODIS $\tau$, CALIPSO $P_{top}$

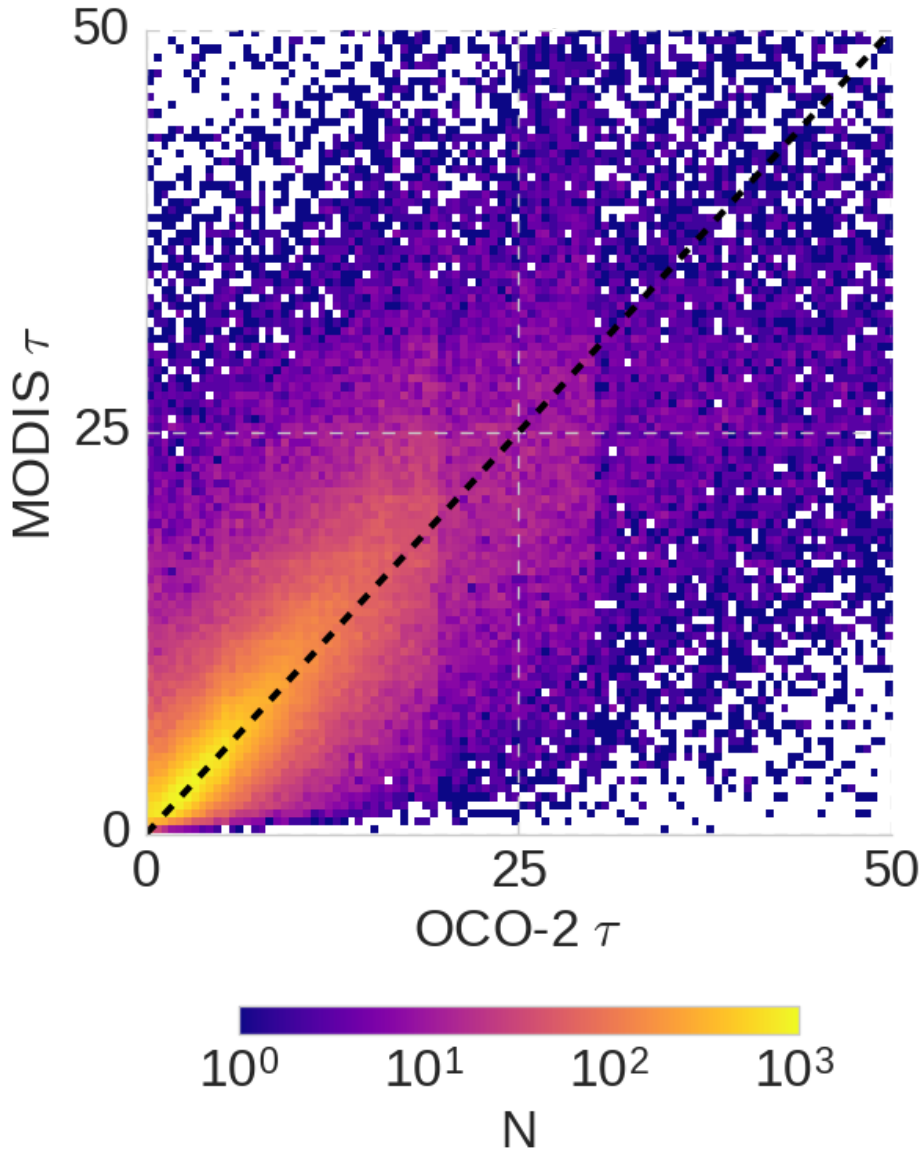


# (7) MODIS and OCO-2 phase agreement

Trained with November 2015, tested on July 2015

| % | OCO-2 liquid | OCO-2 ice |
|---|---|---|
| MODIS liquid | 66.6 | 2.6 |
| MODIS ice | 4.0 | 26.9 |

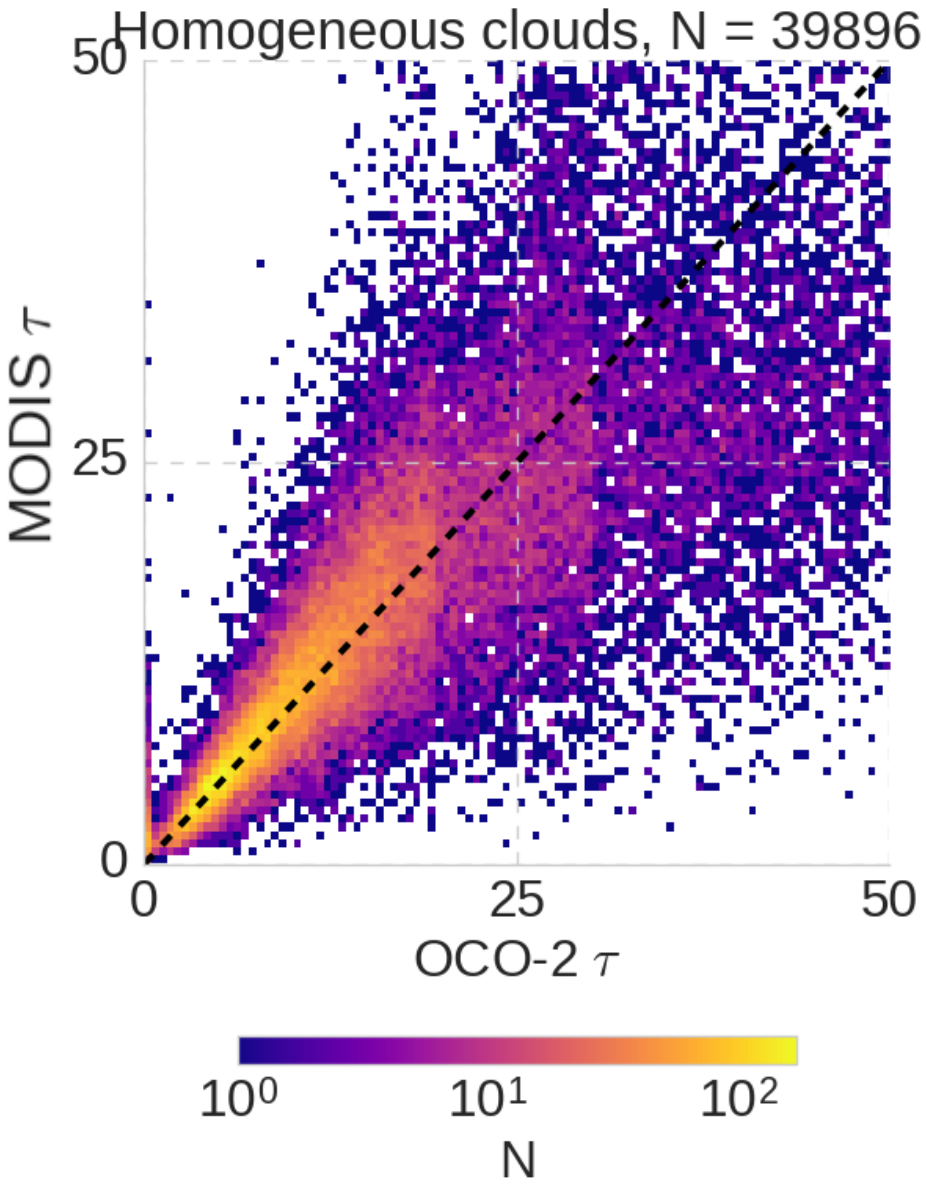
# (8) Cloud optical depth v MODIS I



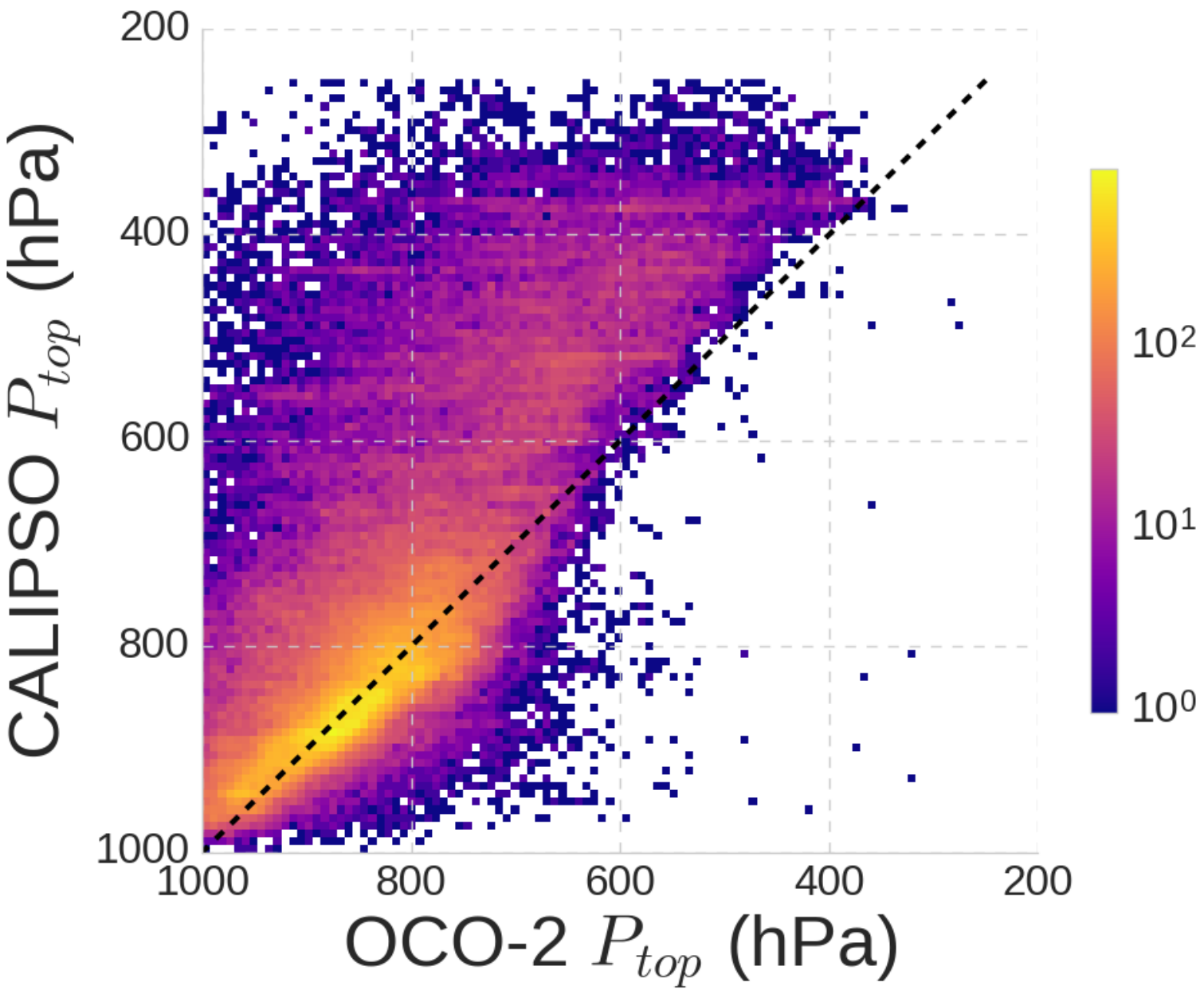

- OCO-2 first guess single-channel retrieval
- All clouds: $\sigma$ of ±6.58
- **COLLOCATION ERROR BETWEEN OCO-2 AND MODIS MEASUREMENTS CONTRIBUTES TO THIS**

# (8) Cloud optical depth v MODIS II

- Homogeneous clouds only show much less scatter (determined from spatial variability of nearby soundings)
- **COLLOCATION ERROR BETWEEN OCO-2 AND MODIS EXPLAINS SOME SCATTER**



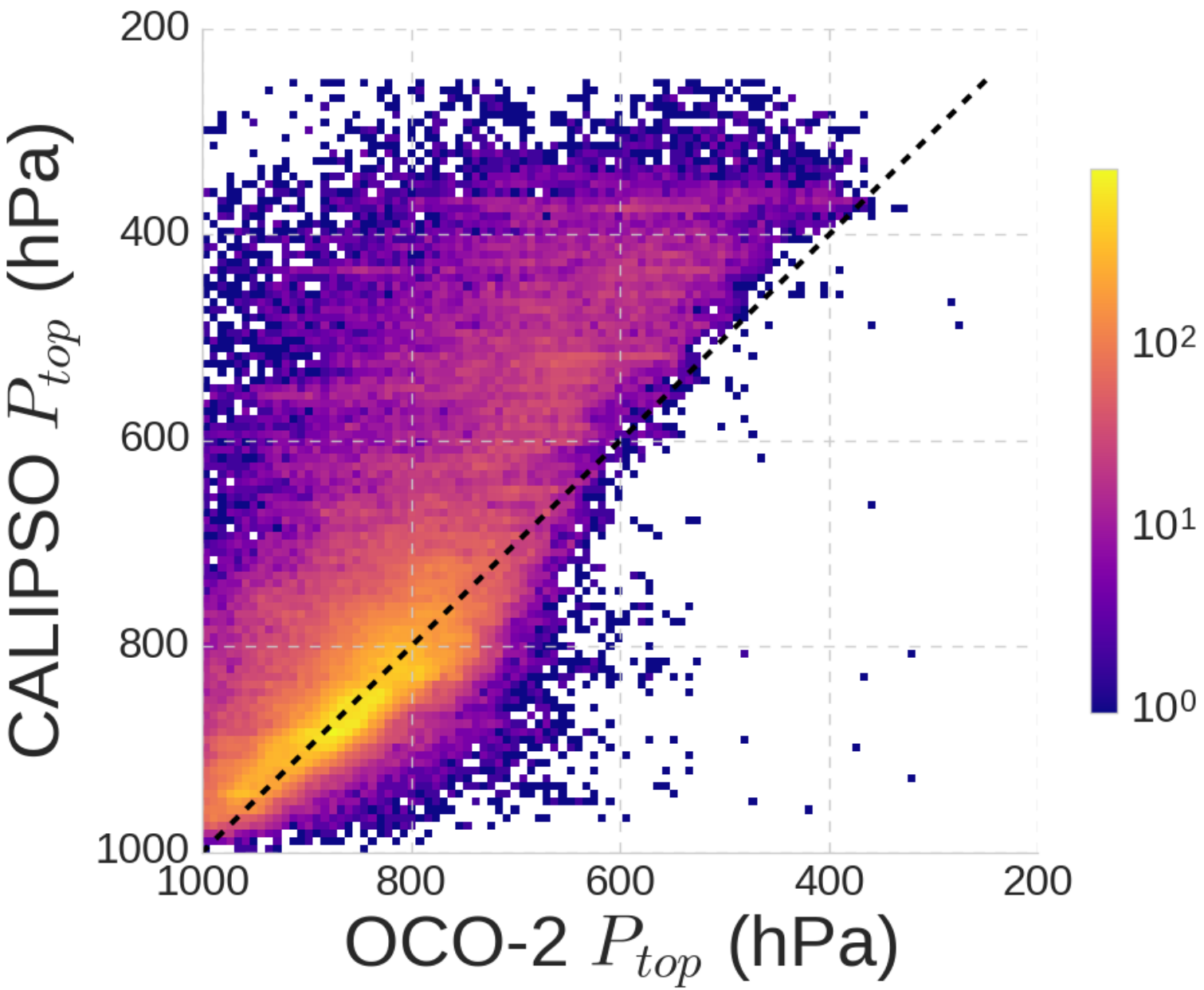
# (9) Cloud-top pressure v CALIPSO I



# (10) Cloud-top pressure v CALIPSO II

**LOW CLOUDS**
**($P_{top} > 680$ hPa)**

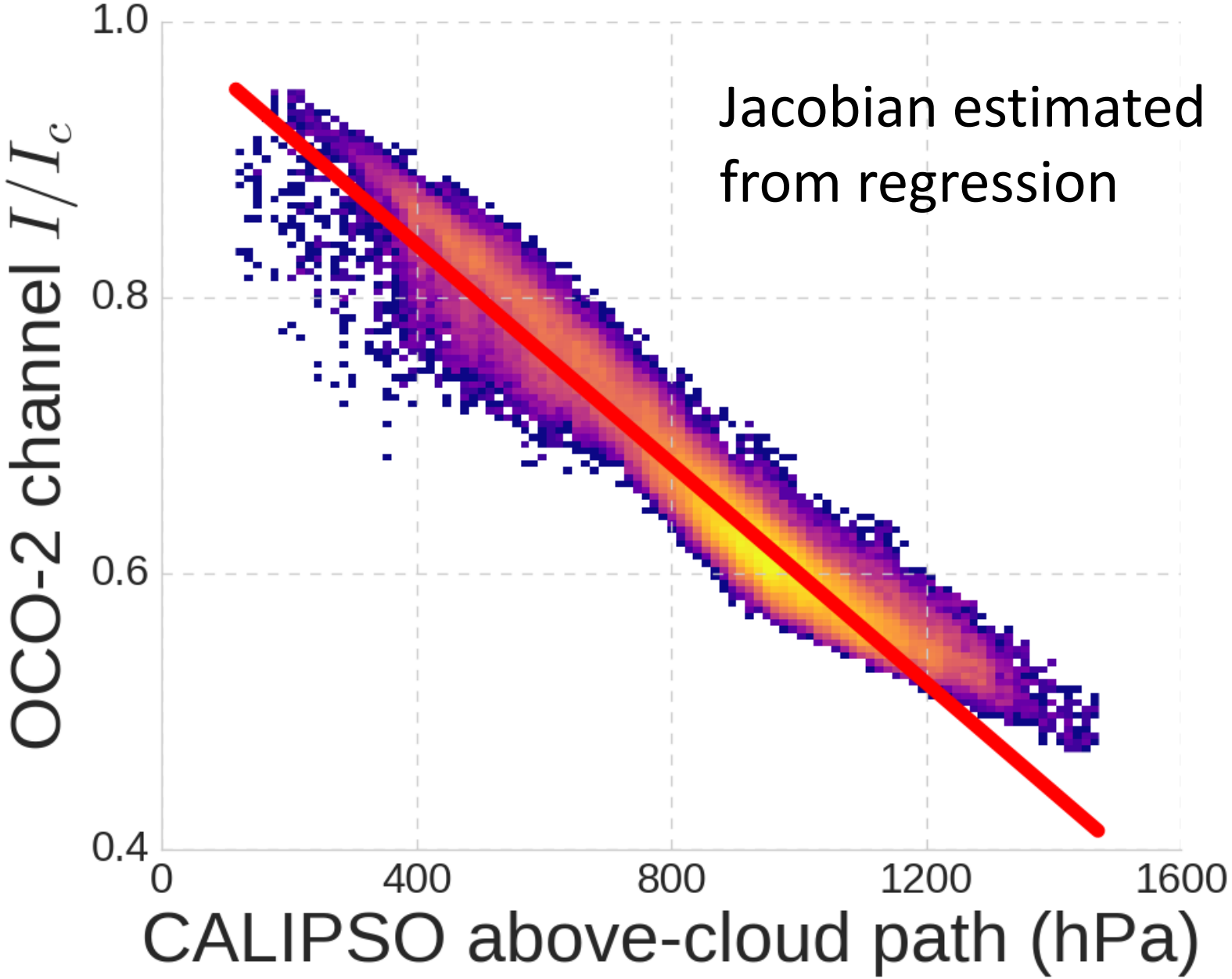
**Bias: 8 hPa**
**$\sigma$: 56 hPa**



# (11) Jacobians I

- Reported validation statistics include variance from assumptions (e.g. single layer, homogeneous…) and collocation v. MODIS/CALIPSO
- Limiting precision can be determined from Jacobians
- Model derived or we can make an empirical estimate by regressing

# (12) Jacobians II

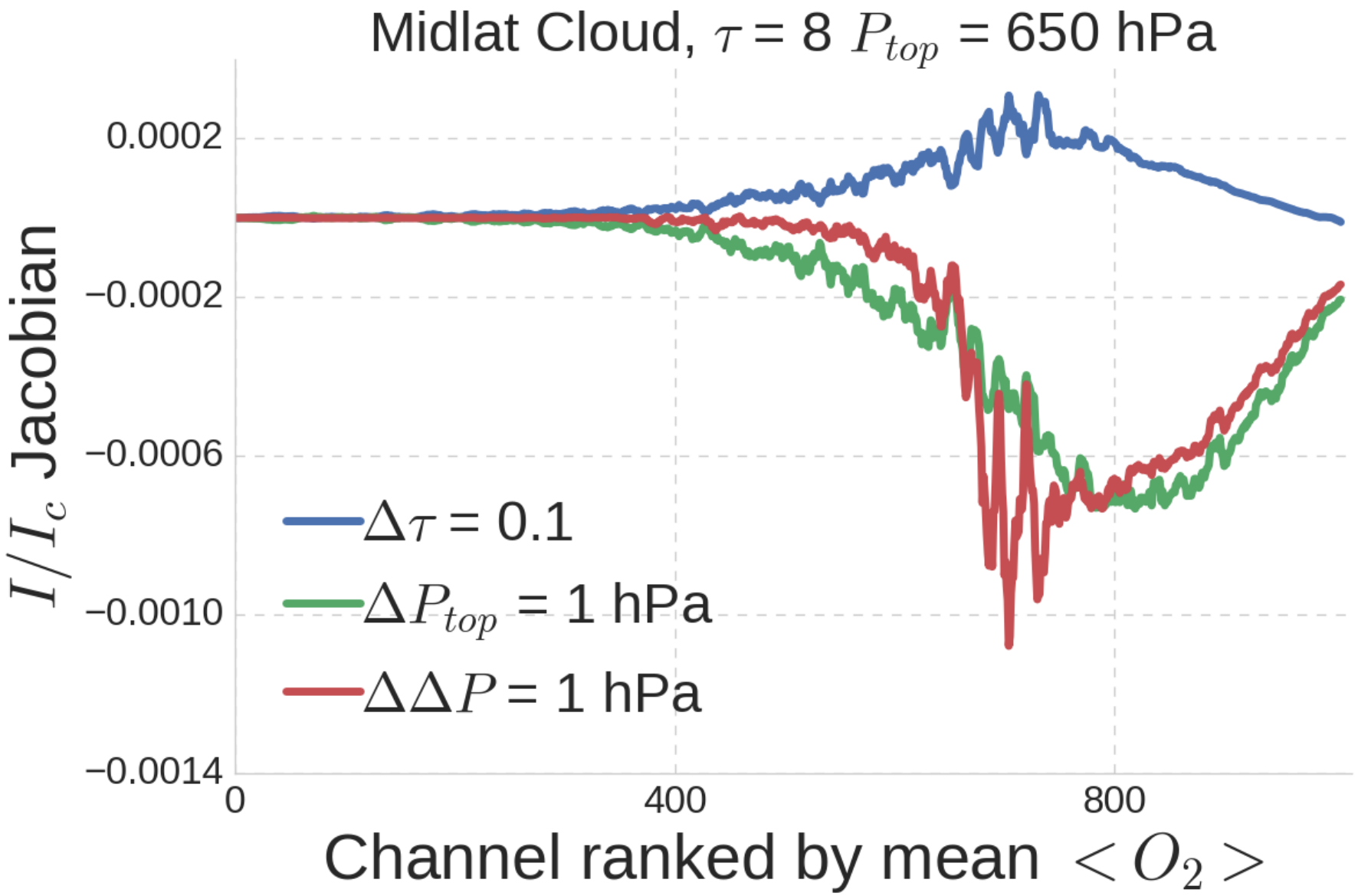


# (13) Jacobians III

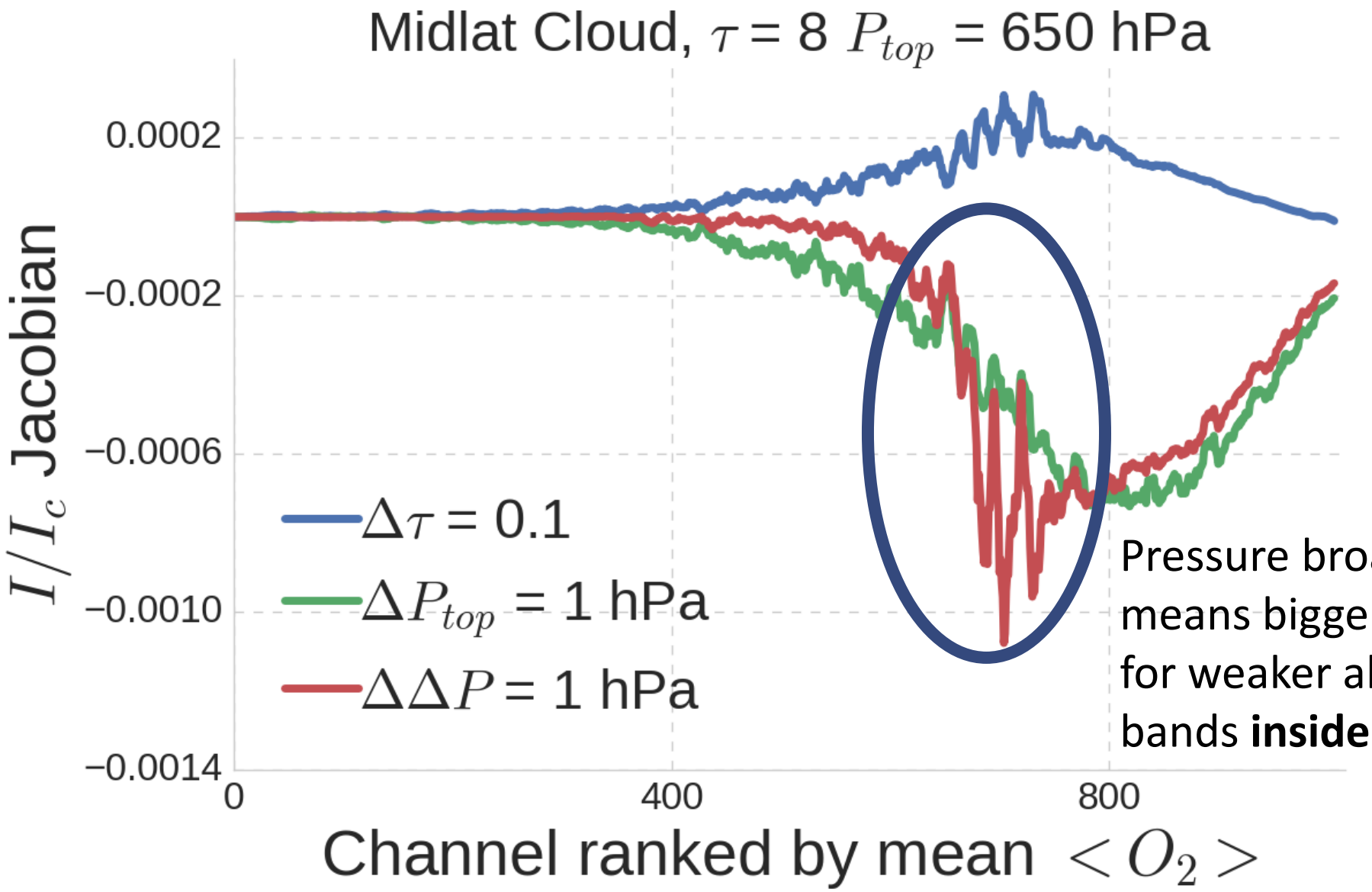
Theoretical **single-channel** precision, similar for both model and observed approximate Jacobians:

$$P_{top} \pm 4.7\ hPa$$
$$\tau \pm 0.03$$

# (14) Jacobians IV

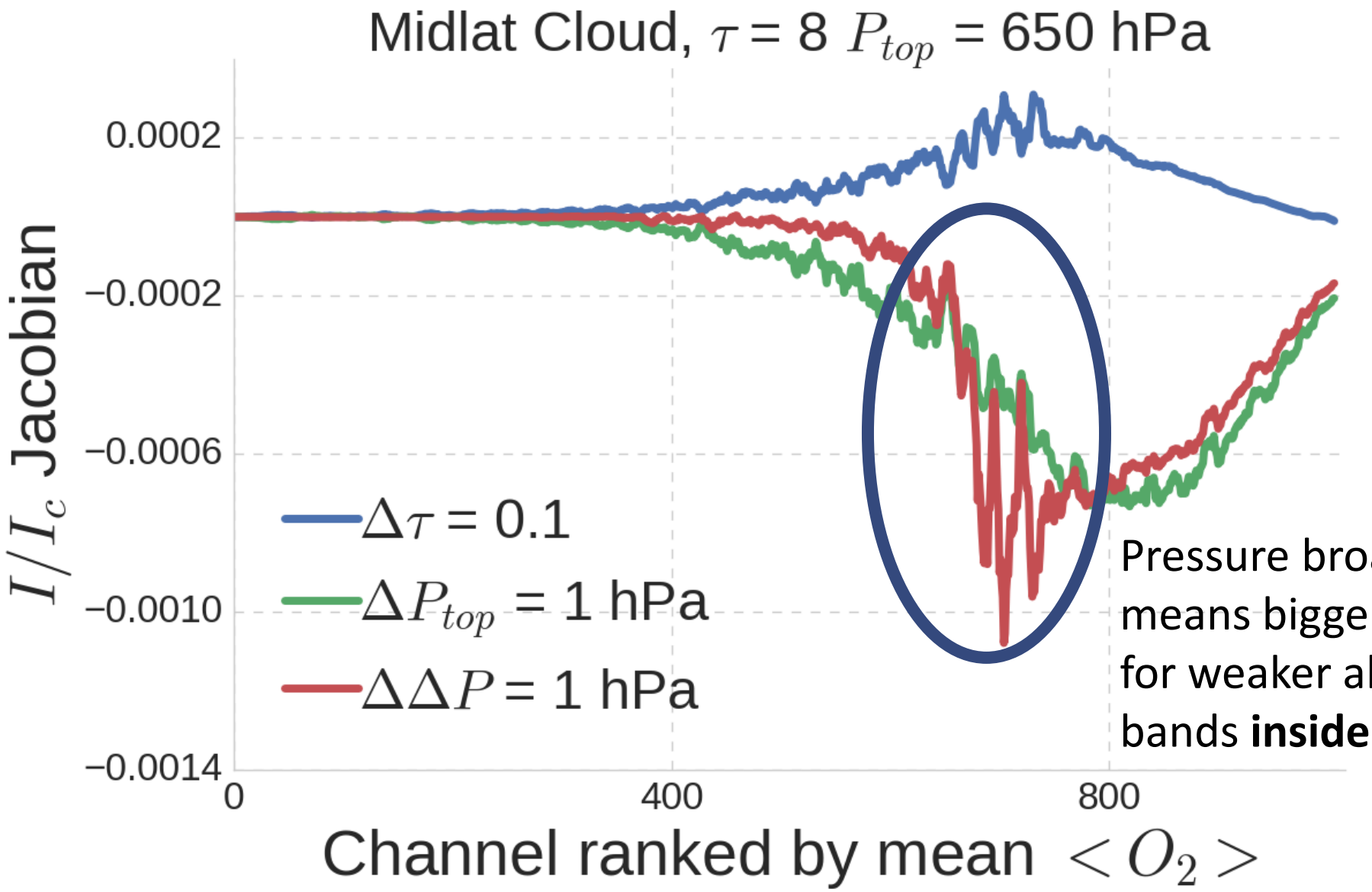


# (14) Jacobians V




Pressure broadening means bigger response for weaker absorption bands **inside** clouds

# (14) Jacobians VI




Pressure broadening means bigger response for weaker absorption bands **inside** clouds

So we can disentangle $P_{top}$ and $\Delta P$

# (15) Coming up

- Formal Bayesian retrieval in development and to be pass to CSU DPC for processing and storage
- Sometime in 2017
- Will be collocated to Cloudsat and stored as a Cloudsat product (OCO-2 products are related to XCO2, SIF only)
- Future work will involve synergy with Cloudsat for cloud layering studies etc.

# (16) Conclusions

- ctP-$\tau$ first-guess retrievals validated vs MODIS-CALIPSO, much spread from collocation (and layering?)
- Theoretical precision from **observed** radiance response is $\tau \pm 0.03$, ctP±4.7 hPa
- We can (theoretically) disentangle ctP and pressure thickness.
- Watch the Cloudsat site.