# Aerosol remote sensing in the vicinity of clouds

J. Redemann, Q. Zhang, P. Russell, B. Schmid

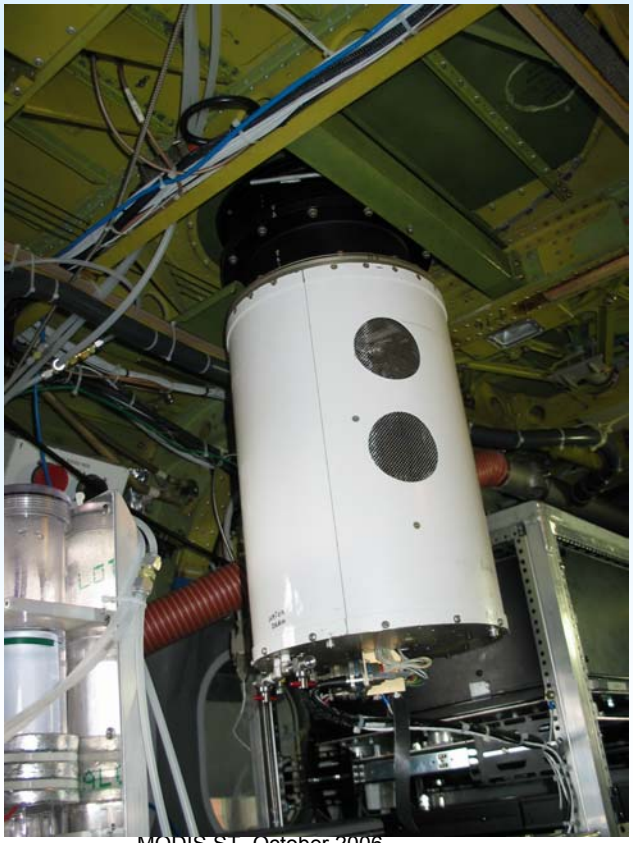
BAER Institute / NASA Ames Research Center / PNNL

http://geo.arc.nasa.gov/AATS-website/

email: jredemann@mail.arc.nasa.gov

# Outline

- Update on SWIR AOD validation and variability between level-2 retrievals
- Motivation: Remote sensing of aerosols in the vicinity of clouds: why?
  - Cloud screening
  - Aerosol indirect effects
- Results from airborne aerosol observations
- Results from simultaneous satellite and airborne aerosol observations
- Summary / Future tasks



1. Measures direct solar beam transmission @:
   353.5 380.0 449.0 499.4 525.0
   605.7 675.1 778.4 864.5 939.7
   1019.1 1241.3 1557.8 2139.0 nm

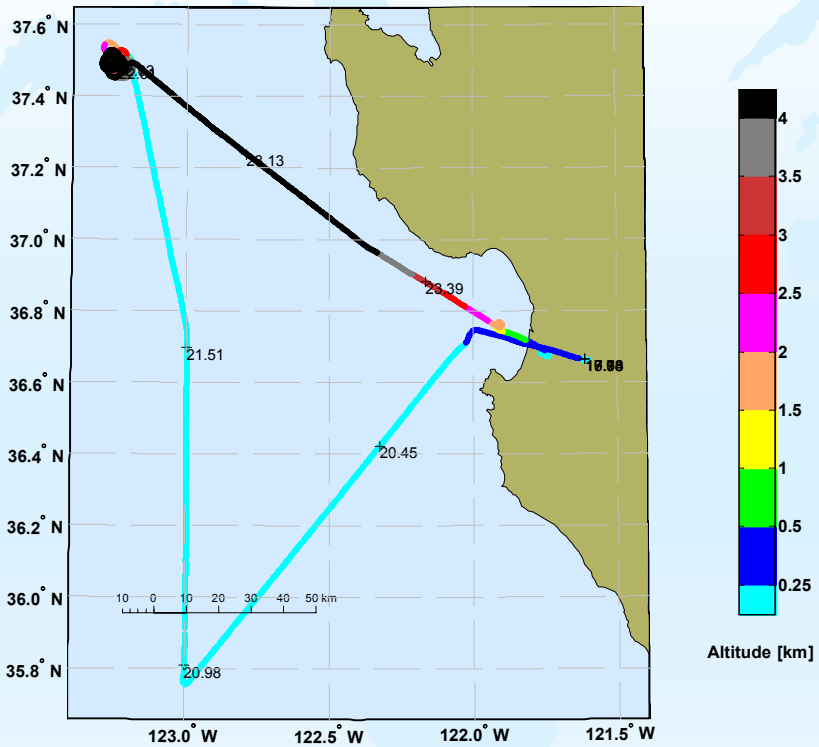
2. Yields:
   aerosol optical depth + aerosol extinction when A/C flies profiles

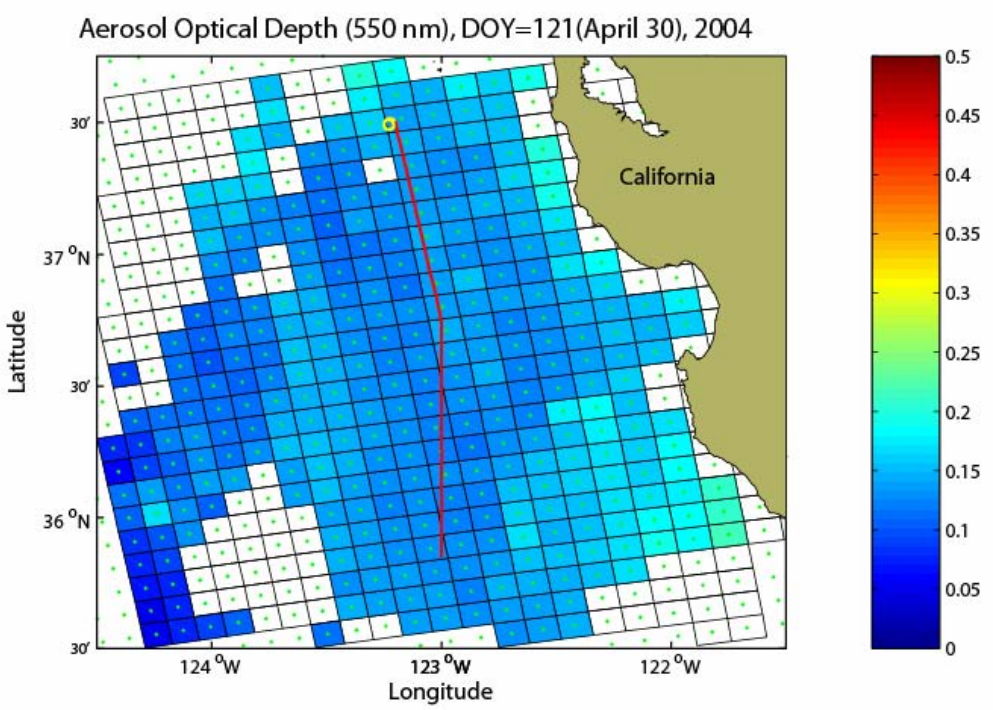
   columnar water vapor (ozone) + water vapor (ozone) concentration when A/C flies profiles

3. Size:
   Telescope dome 8" OD (hemisphere) atop 5" H pedestal. (Total H: 9" above A/C skin), Inside A/C: 12" D x 18" H cylinder.

4. Weight:
   131.6 lbs

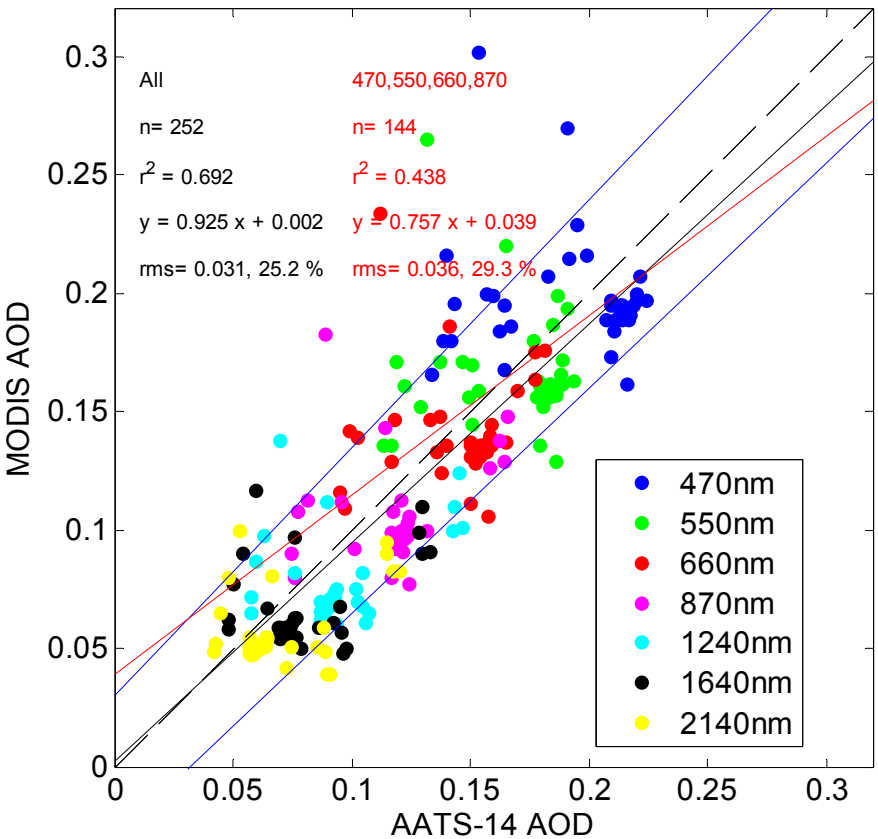
# EVE flight campaign, Flight CIR06, Apr. 30, 2004



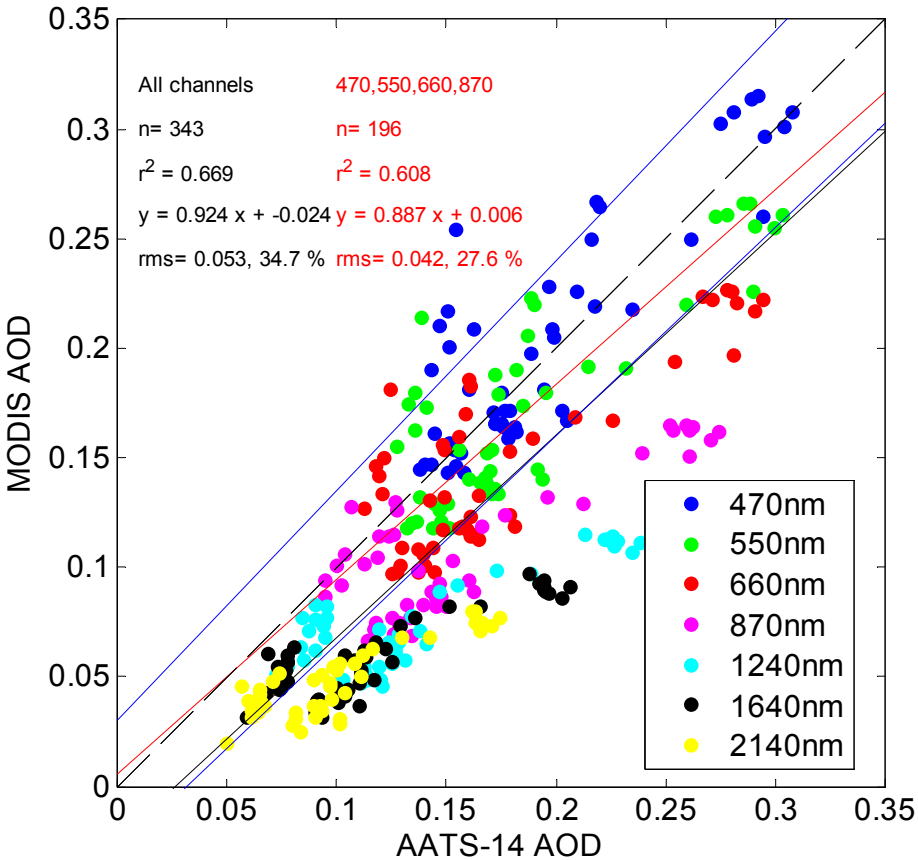



# MODIS AOD validation in EVE, all wavelengths

## MODIS-Terra

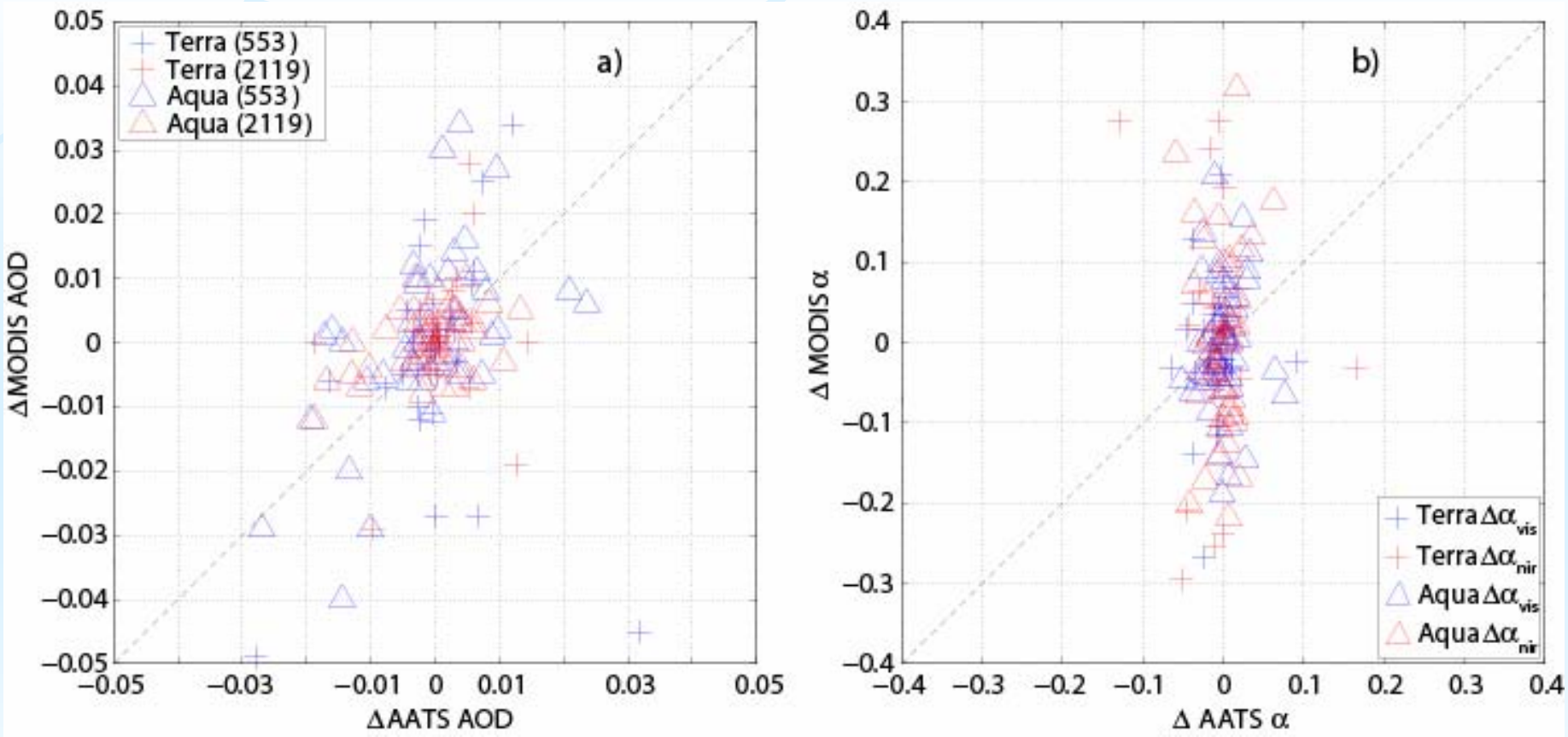



## MODIS-Aqua




Redemann et al., GRL, 2006

# Change in AOD and $\alpha$ between adjacent level-2 retrievals

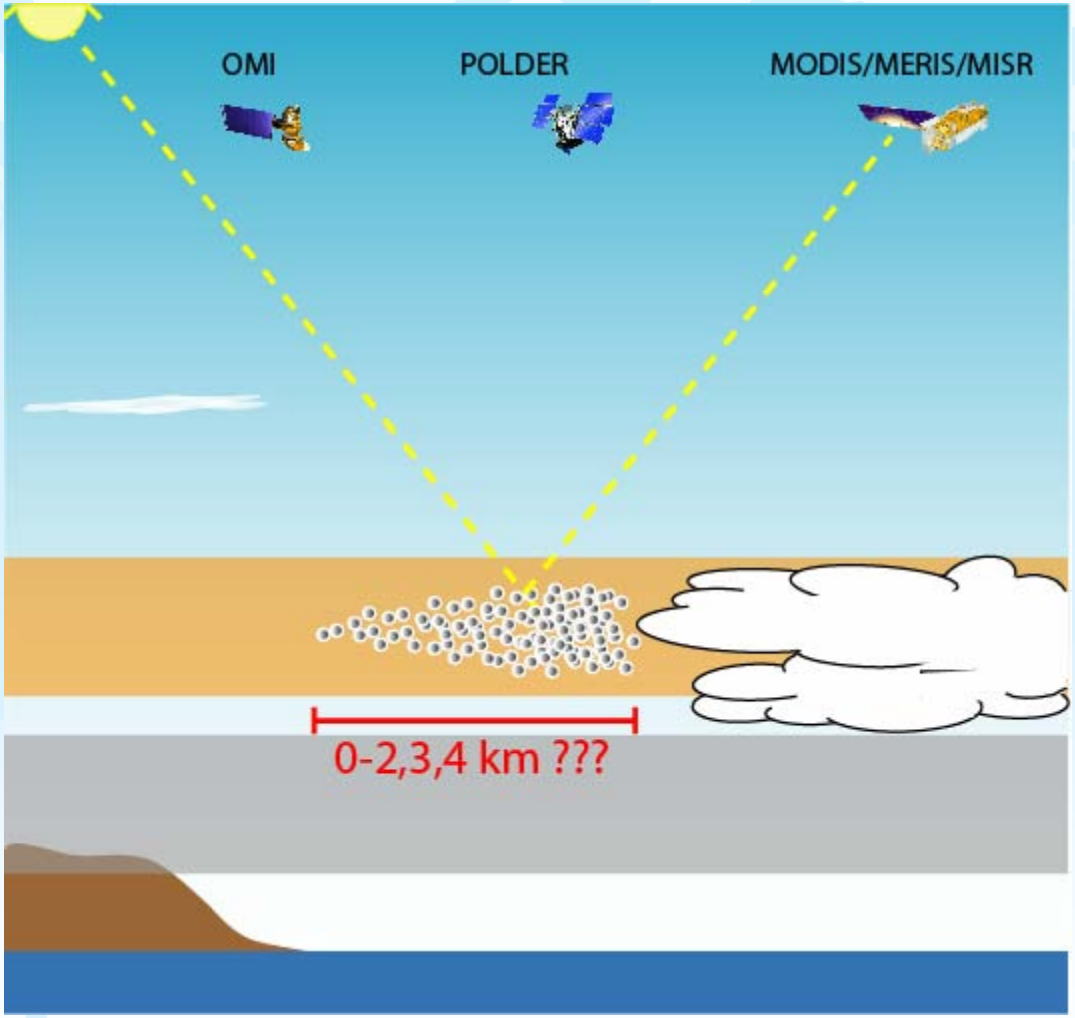


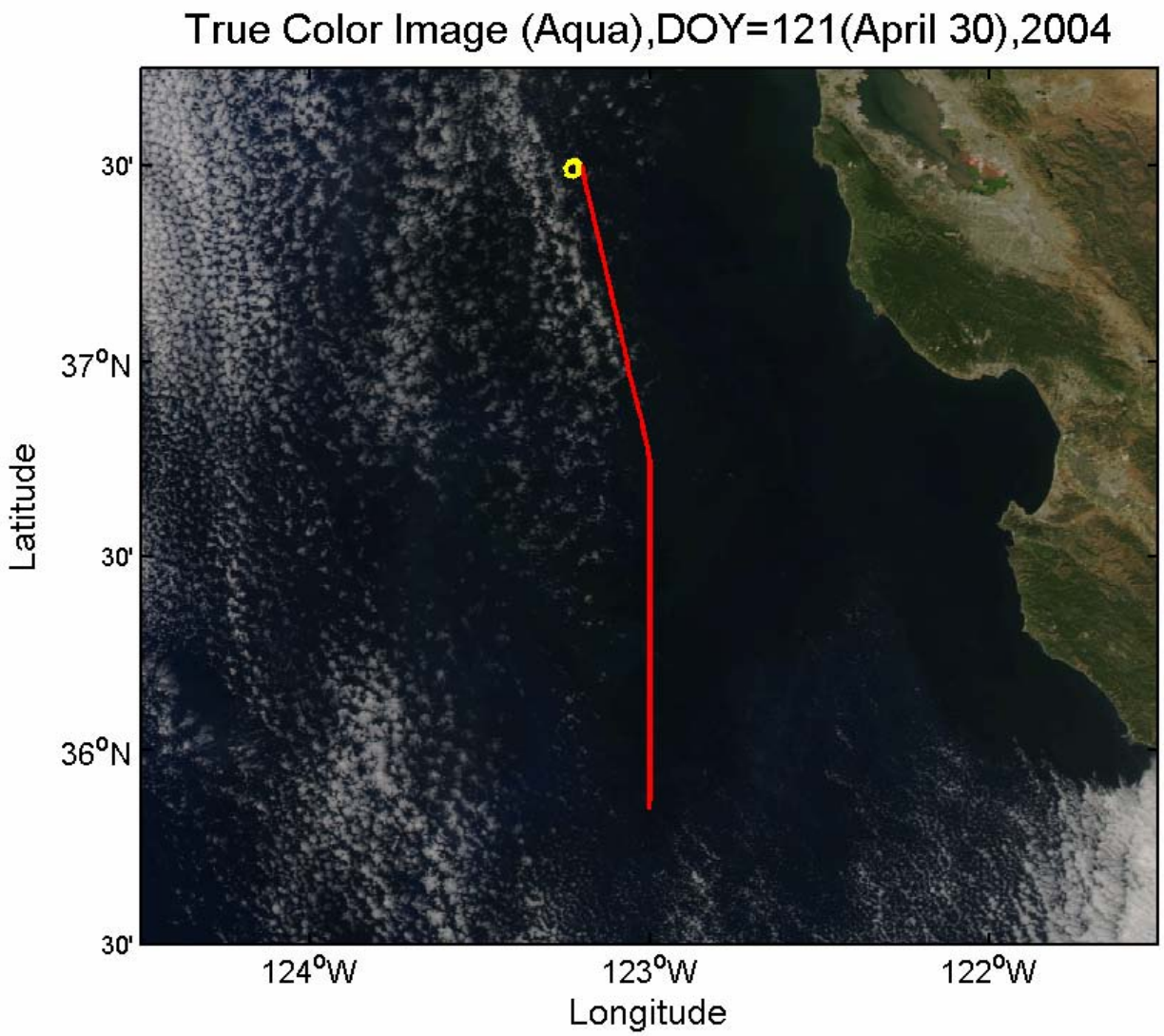

Redemann et al., GRL, 2006

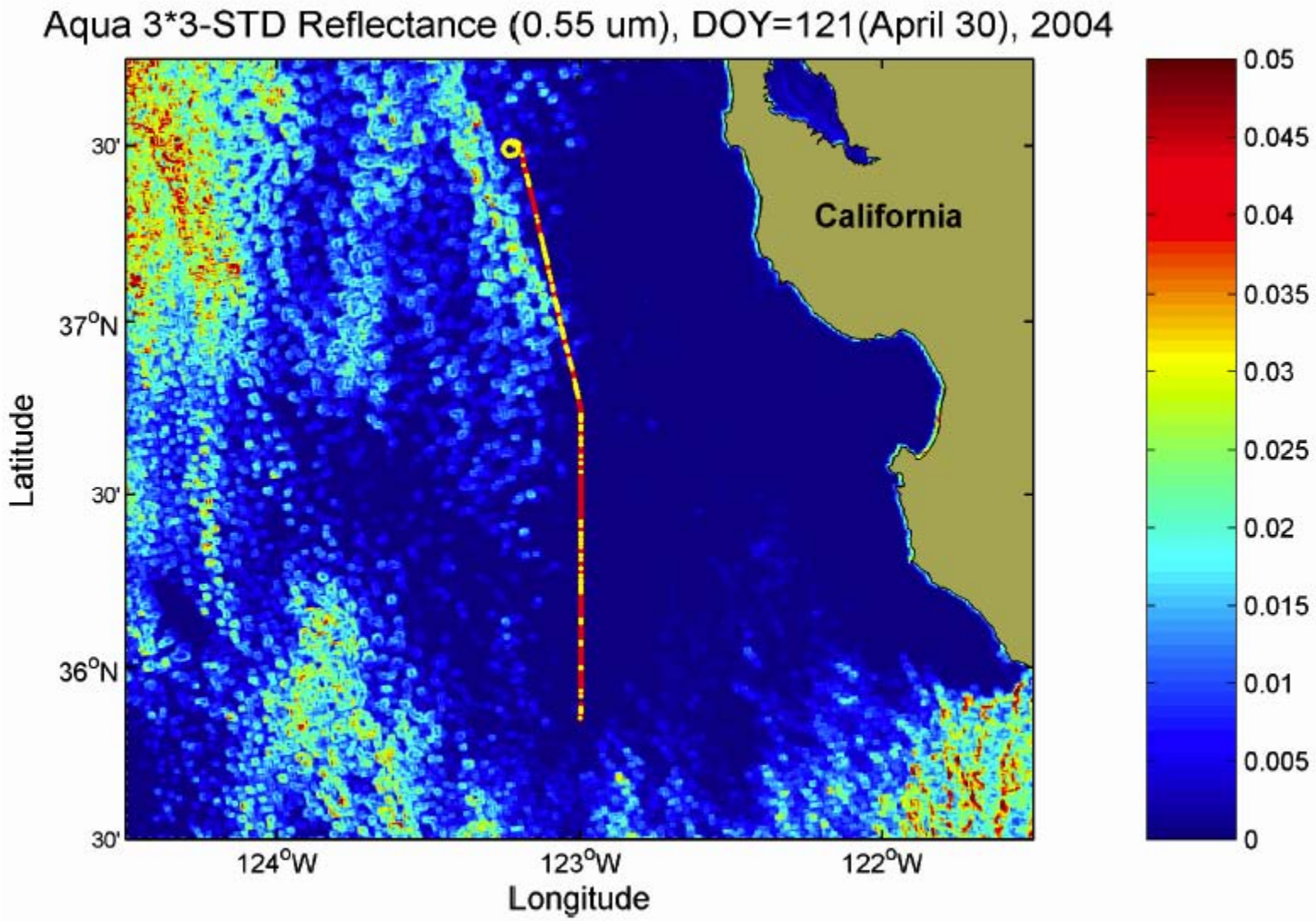
# Change in AOD and α between adjacent level-2 retrievals

| | Variable | **MODIS-Terra** | AATS-14 | **MODIS-Aqua** | AATS-14 |
|---|---|---|---|---|---|
| AOD | Mean/Mode of $\lvert\Delta\tau(553nm)\rvert$ | 0.015/0.005 | 0.006/0.000 | 0.009/0.002 | 0.007/0.000 |
| AOD | Mean/Mode of $\lvert\Delta\tau(2119nm)\rvert$ | 0.003/0.000 | 0.005/0.000 | 0.004/0.000 | 0.005/0.000 |
| AOD | Lag-1, *r(15 km)* of $\tau(553nm)$ | 0.25 | 0.96 | 0.96 | 0.98 |
| AOD | Lag-1, *r(15 km)* of $\tau(2119nm)$ | 0.84 | 0.96 | 0.96 | 0.98 |
| α | Mean/Mode of $\lvert\Delta\alpha_{vis}\rvert$ | 0.053/0.014 | 0.018/0.000 | 0.066/0.044 | 0.017/0.001 |
| α | Mean/Mode of $\lvert\Delta\alpha_{nir}\rvert$ | 0.092/0.018 | 0.022/0.000 | 0.088/0.000 | 0.016/0.000 |
| α | Lag-1, *r(15 km)* of $\Delta\alpha_{vis}$ | 0.88 | 0.99 | 0.85 | 0.99 |
| α | Lag-1, *r(15 km)* of $\Delta\alpha_{nir}$ | 0.42 | 0.97 | 0.85 | 0.98 |

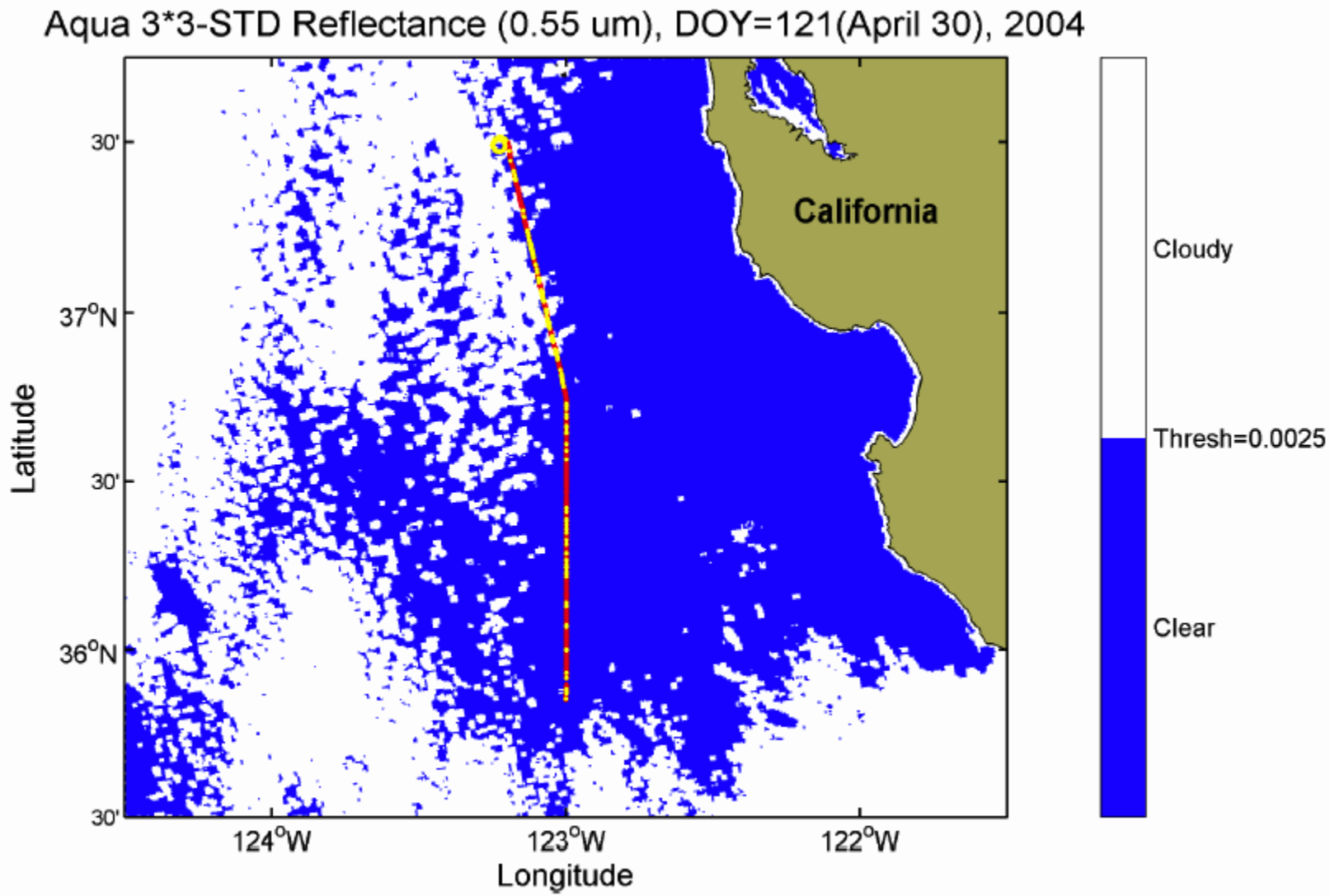
# Motivation: Simultaneous satellite and airborne aerosol remote sensing in the vicinity of clouds: why?

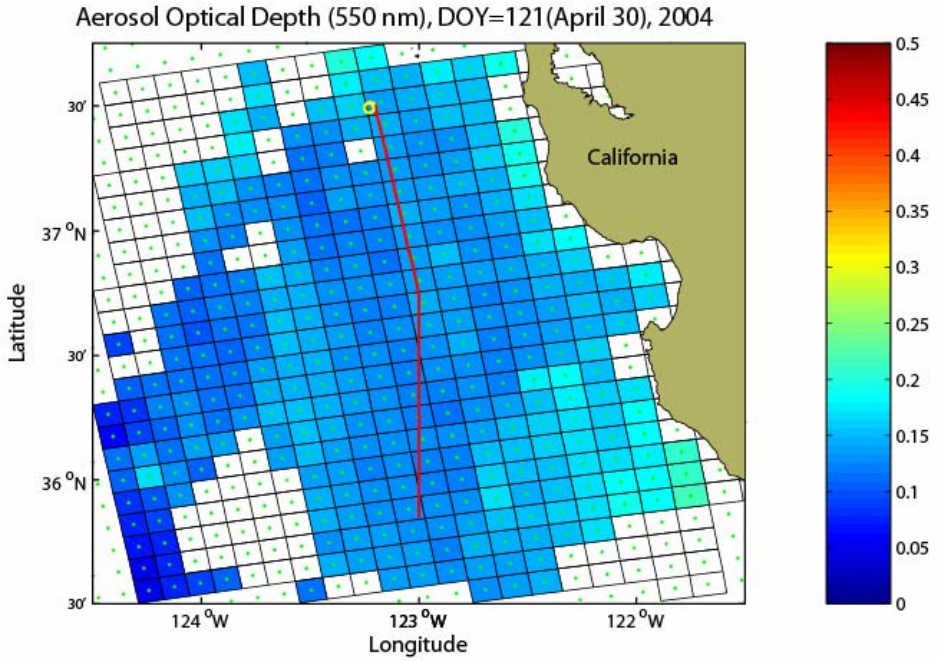


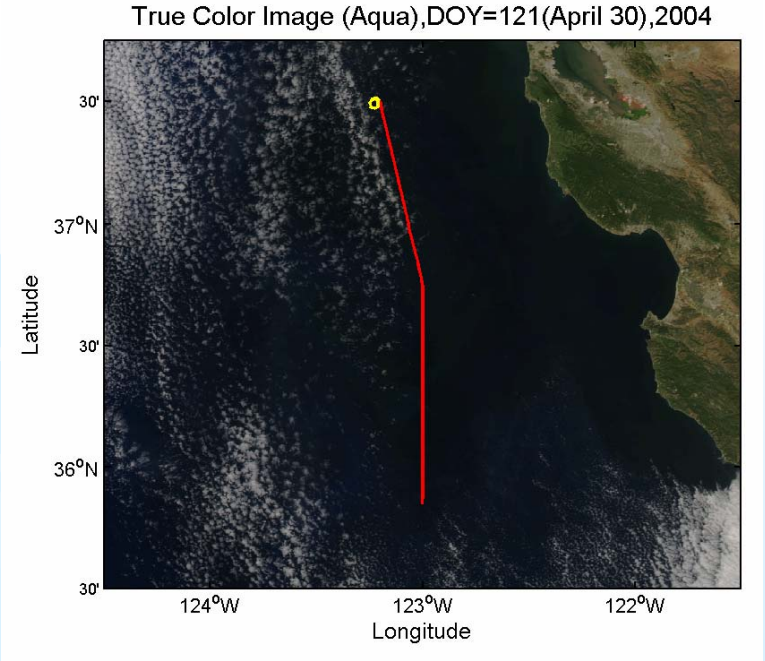

True Color Image (Aqua),DOY=121(April 30),2004
30'
37°N
30'
36°N
30'
Latitude
124°W
123°W
122°W
Longitude

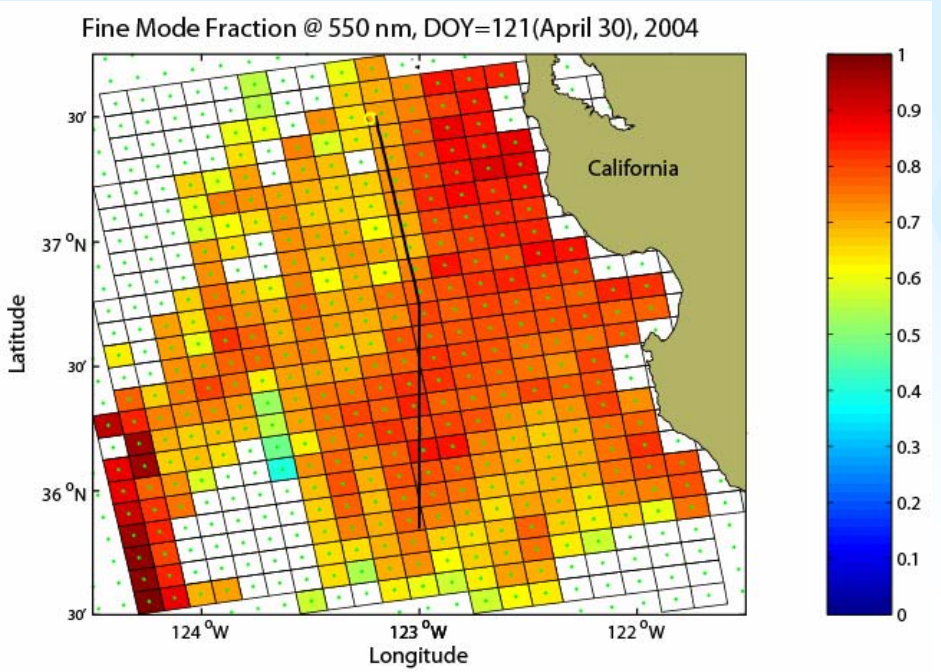

Aqua 3*3-STD Reflectance (0.55 um), DOY=121(April 30), 2004
California
Latitude
30'
37°N
30'
36°N
30'
124°W
123°W
122°W
Longitude
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0

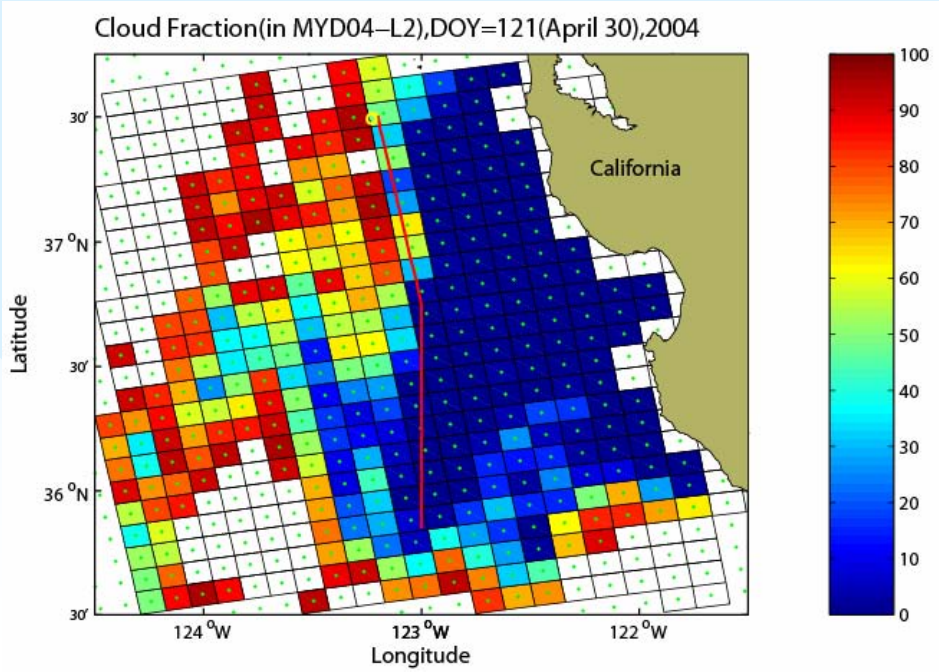
# Cloud fraction from aerosol algorithm = 60.2%



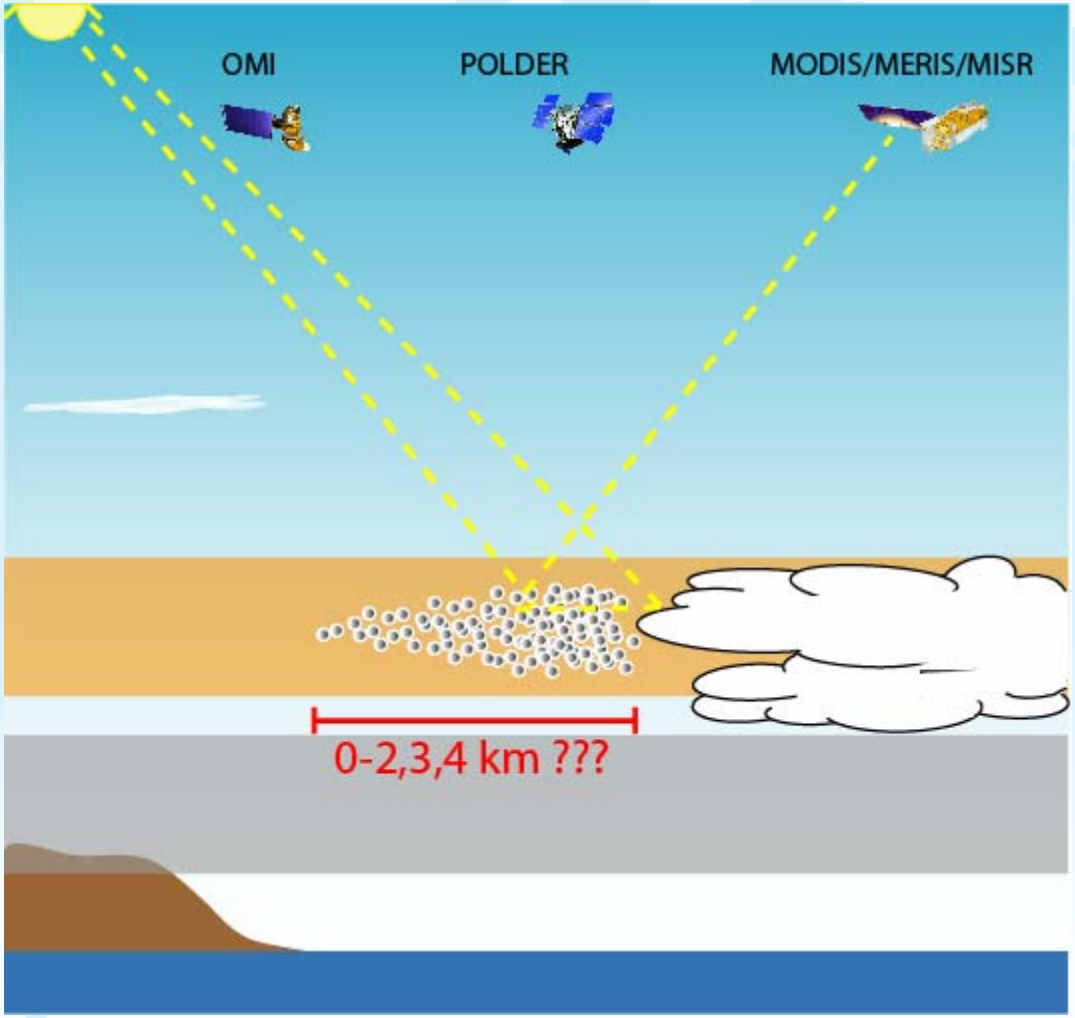

Aerosol Optical Depth (550 nm), DOY=121(April 30), 2004
California
Latitude
Longitude
30'
37 °N
36 °N
124 °W
123 °W
122 °W
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0


True Color Image (Aqua),DOY=121(April 30),2004
Latitude
Longitude
30'
37°N
36°N
124°W
123°W
122°W

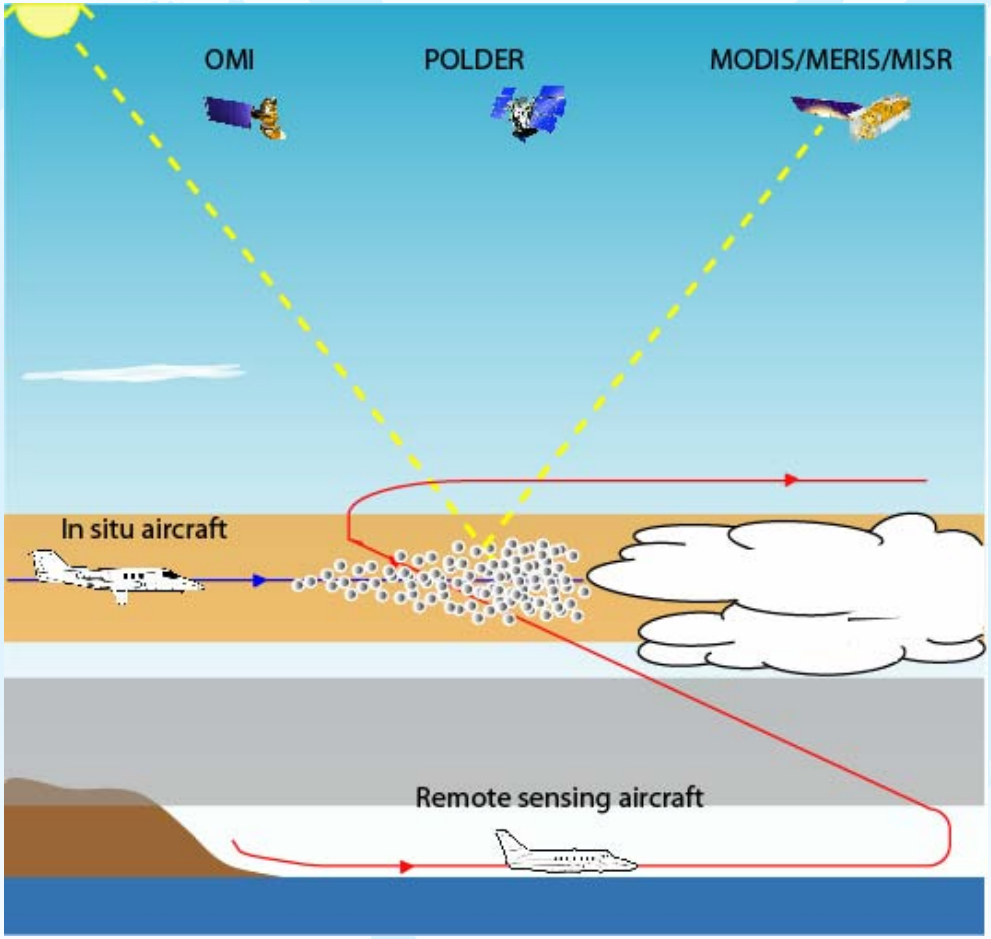

Fine Mode Fraction @ 550 nm, DOY=121(April 30), 2004
California
Latitude
Longitude
30'
37 °N
36 °N
124 °W
123 °W
122 °W
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


Cloud Fraction(in MYD04–L2),DOY=121(April 30),2004
California
Latitude
Longitude
30'
37 °N
36 °N
124 °W
123 °W
122 °W
100
90
80
70
60
50
40
30
20
10
0

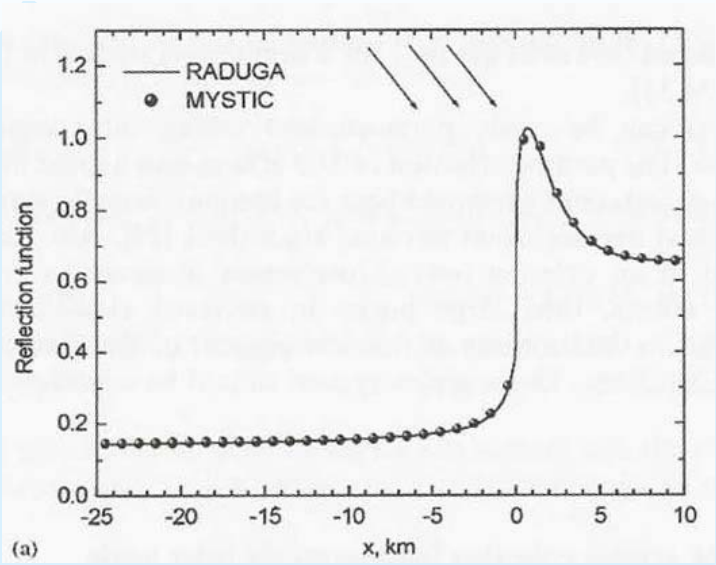
# Motivation: Simultaneous satellite and airborne aerosol remote sensing in the vicinity of clouds - challenges



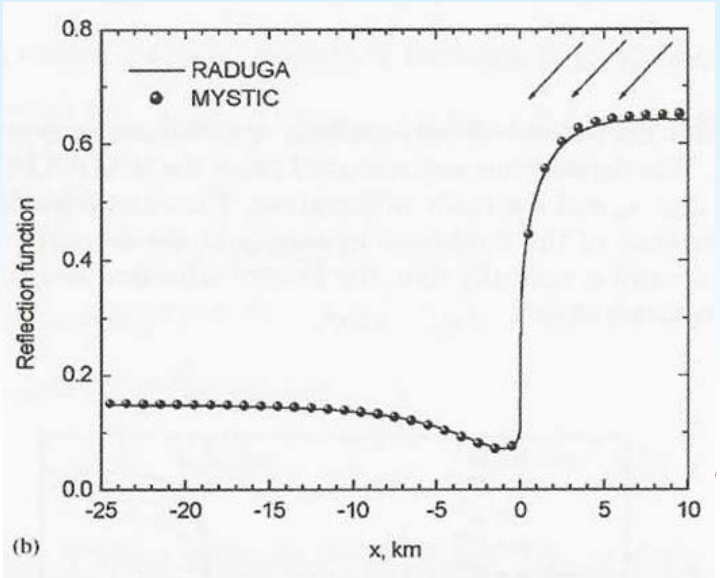
# Motivation: Simultaneous satellite and airborne aerosol remote sensing in the vicinity of clouds




Cloud brightening

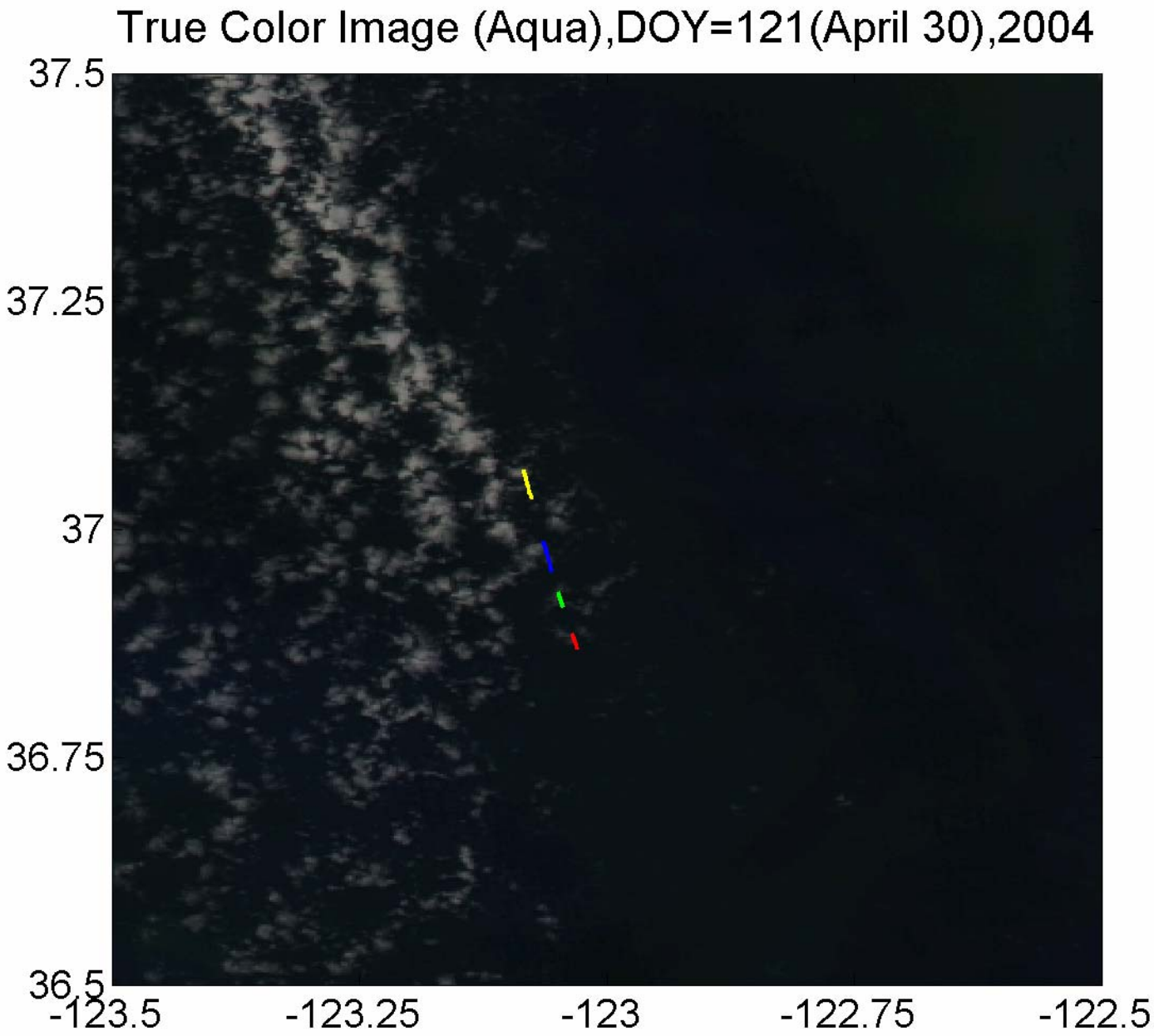


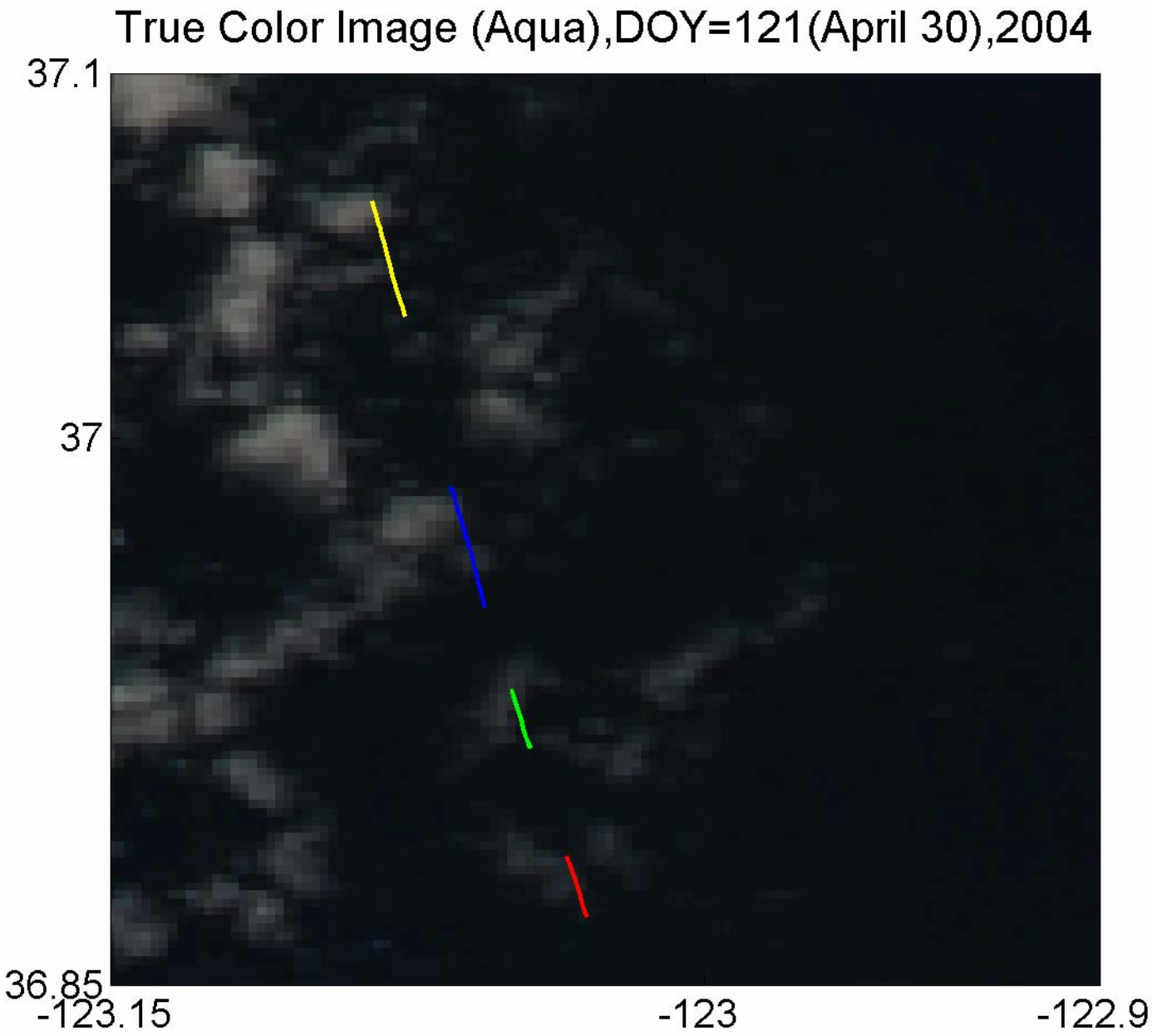

Cloud shadowing

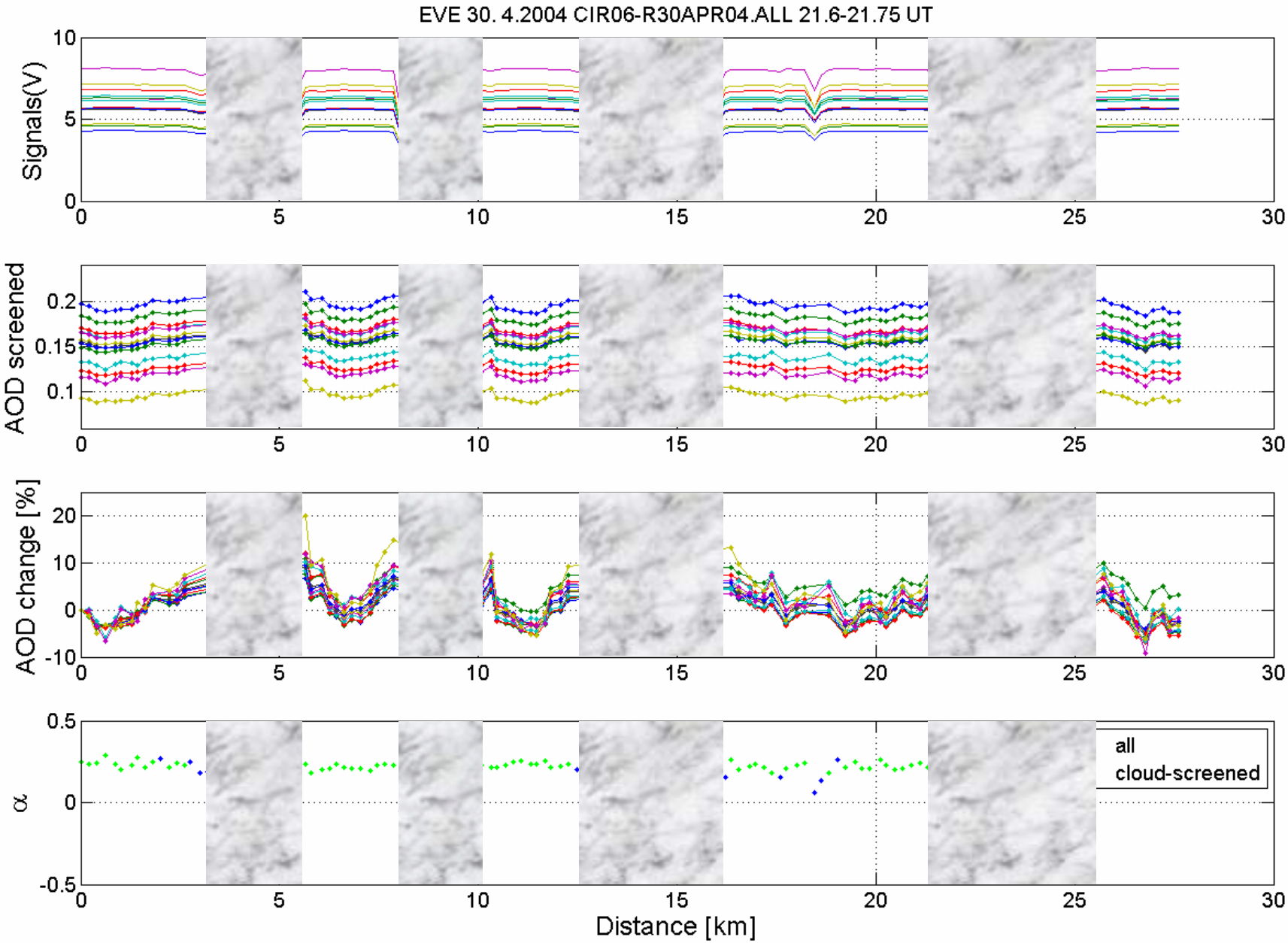



Nikolaeva et al., JQSRT, 2005

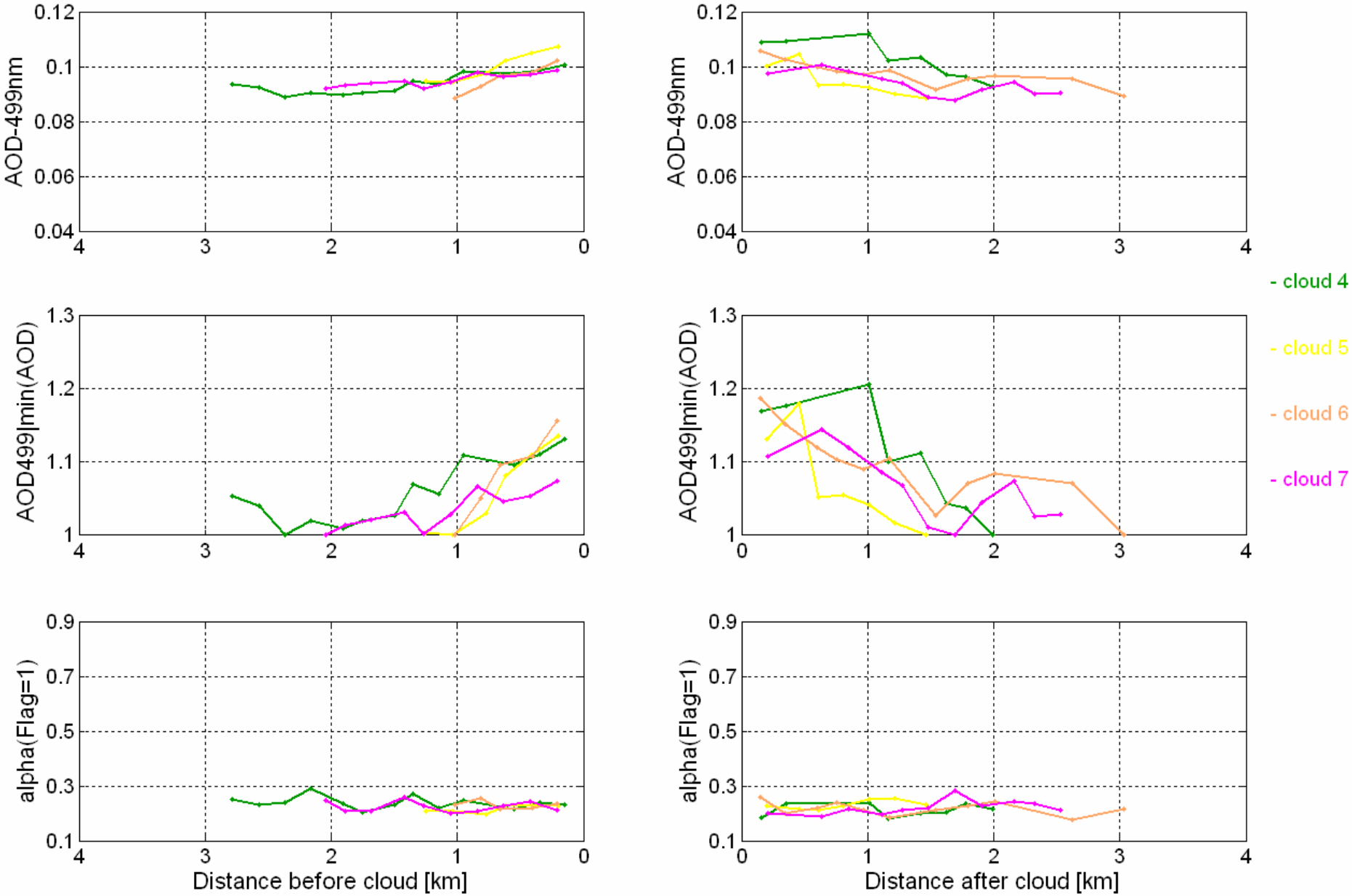
see also, Wen et al., Marshak et al.


True Color Image (Aqua),DOY=121(April 30),2004
37.5
37.25
37
36.75
36.5
-123.5
-123.25
-123
-122.75
-122.5

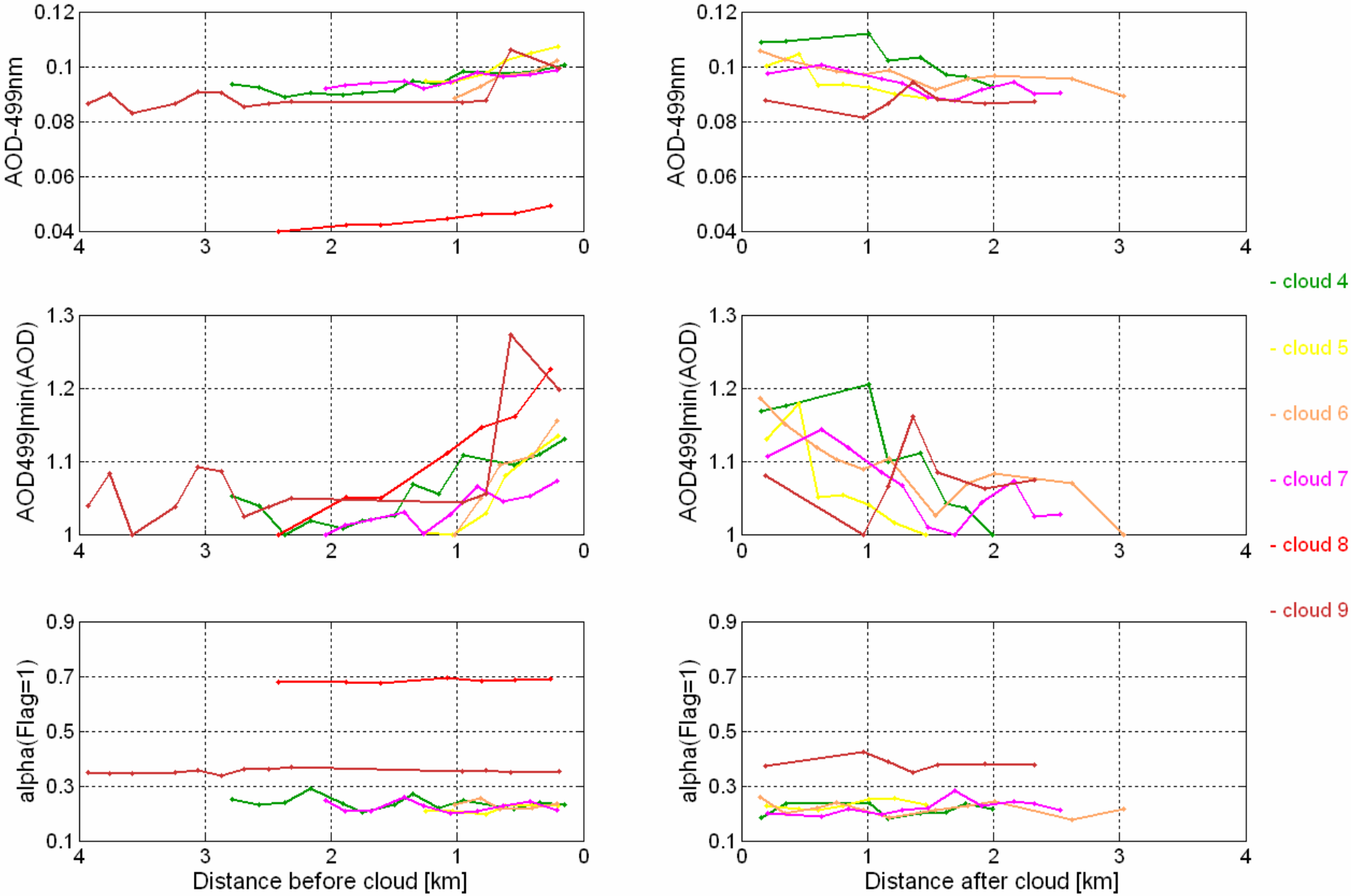

True Color Image (Aqua),DOY=121(April 30),2004
37.1
37
36.85
-123.15
-123
-122.9


EVE 30. 4.2004 CIR06-R30APR04.ALL 21.6-21.75 UT
Signals(V)
AOD screened
AOD change [%]
α
all
cloud-screened
Distance [km]

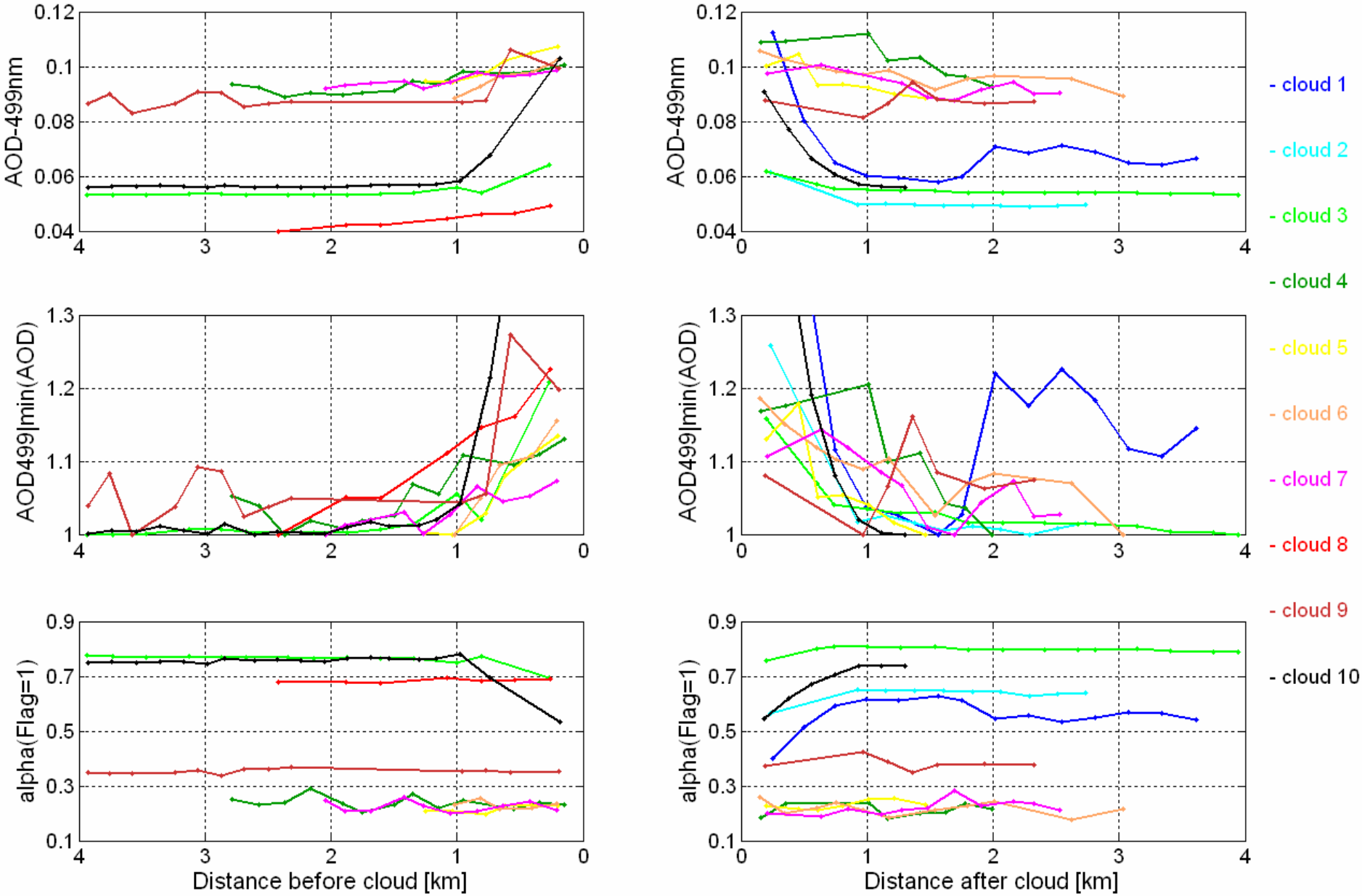
cloud 1 -- cloud 10 (AOD and Alpha)

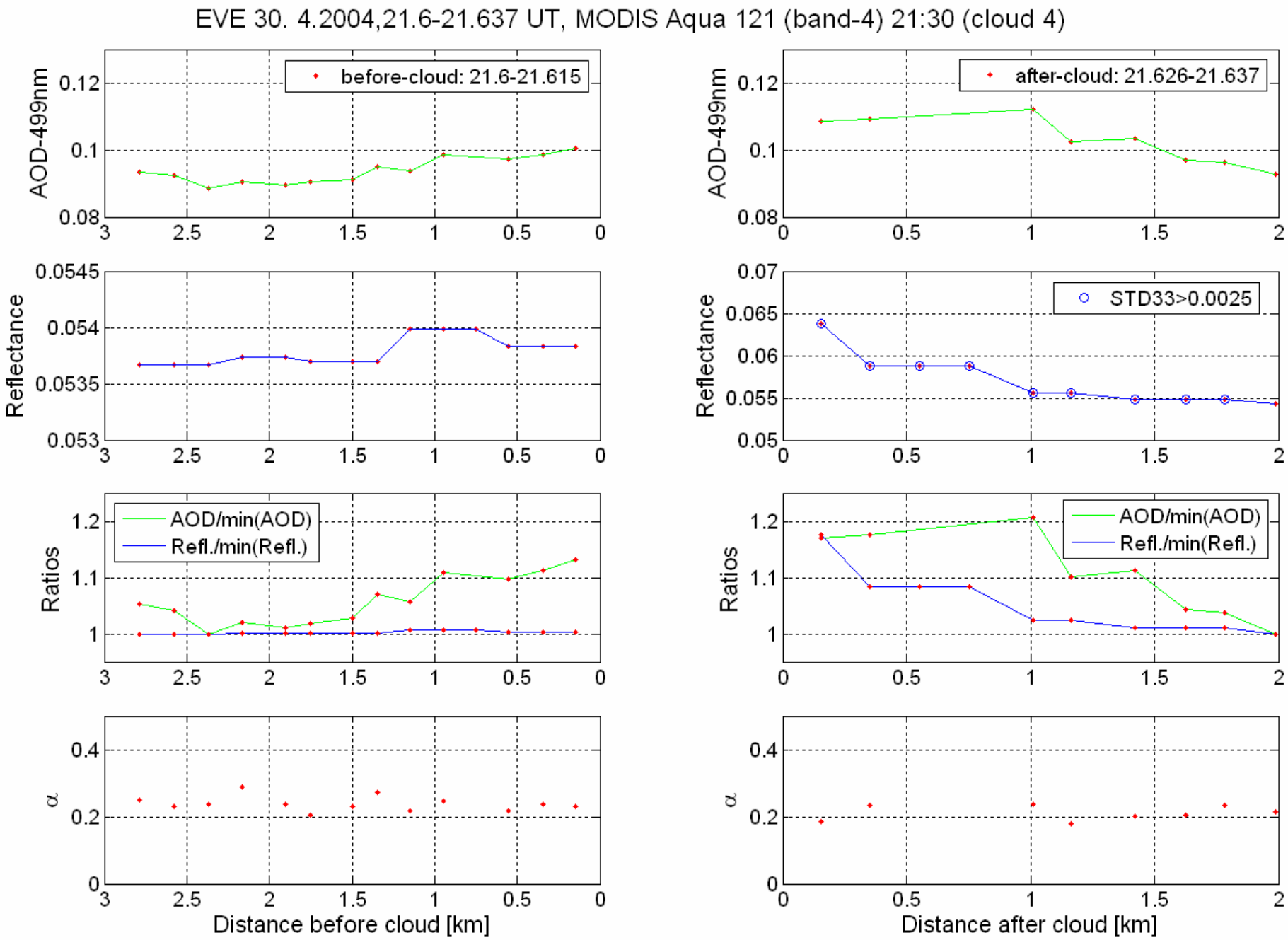


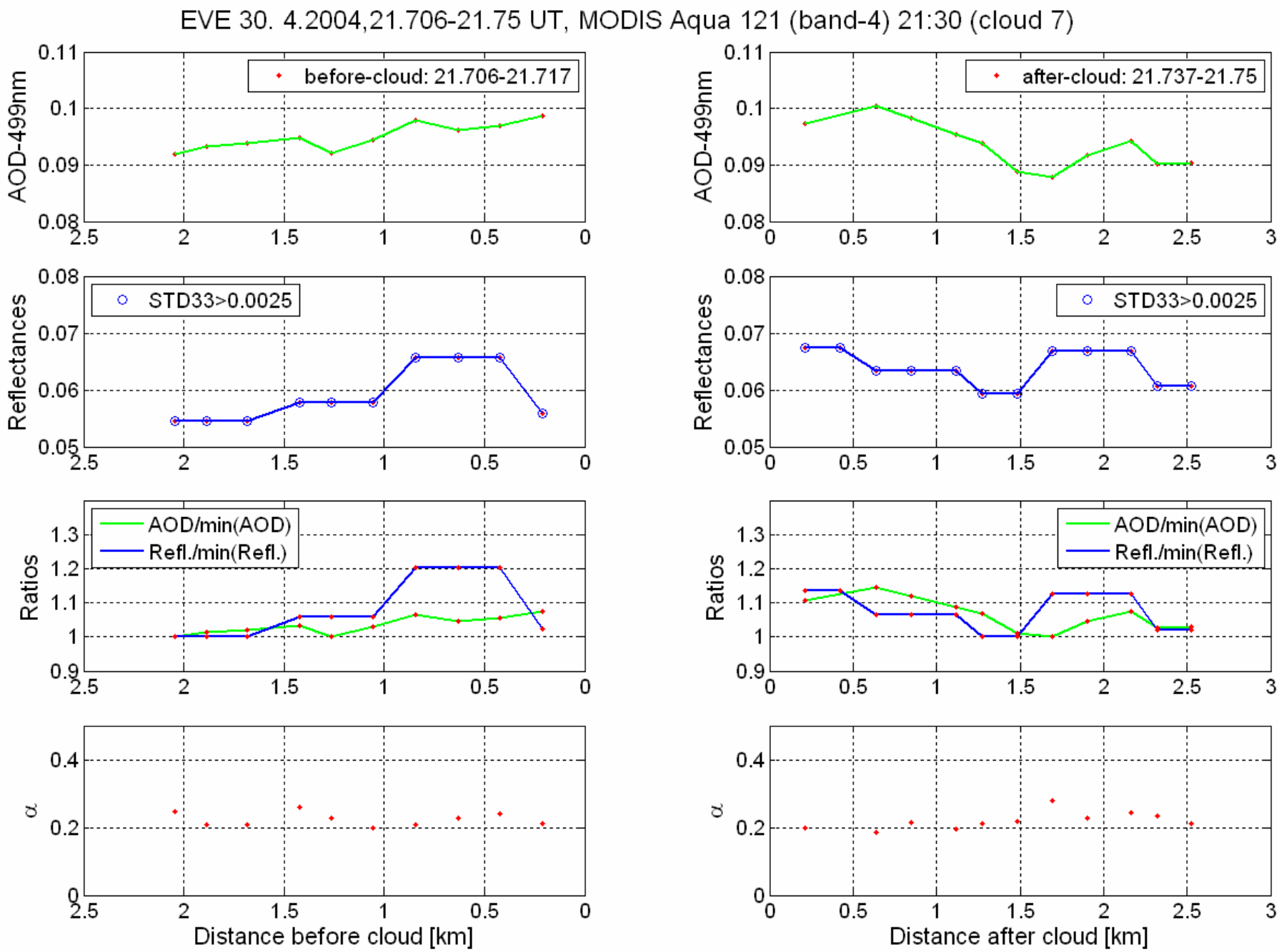
cloud 1 -- cloud 10 (AOD and Alpha)



cloud 1 -- cloud 10 (AOD and Alpha)




EVE 30. 4.2004,21.6-21.637 UT, MODIS Aqua 121 (band-4) 21:30 (cloud 4)
before-cloud: 21.6-21.615
after-cloud: 21.626-21.637
AOD-499nm
Reflectance
STD33>0.0025
Ratios
AOD/min(AOD)
Refl./min(Refl.)
α
Distance before cloud [km]
Distance after cloud [km]


EVE 30. 4.2004,21.706-21.75 UT, MODIS Aqua 121 (band-4) 21:30 (cloud 7)
before-cloud: 21.706-21.717
after-cloud: 21.737-21.75
AOD-499nm
Reflectances
STD33>0.0025
Ratios
AOD/min(AOD)
Refl./min(Refl.)
α
Distance before cloud [km]
Distance after cloud [km]

# Summary/Conclusions

1) The study of the aerosol-cloud boundary is essential for understanding appropriate cloud screening methods in aerosol remote sensing and for investigating the aerosol indirect effect on climate.
2) In a preliminary study of suborbital AOD data near cloud edges in a field experiment conducted off the Northern CA coast, we found that in ~75% of the cases there was an increase of 5-25% in AOD in the closest 2 km near the clouds. In the case of dissipating stratiform clouds, the change in AOD was mostly linear and not accompanied by a discernible change in aerosol size.
3) Concurrently, the MODIS-observed mid-visible reflectances in the vicinity of the suborbital cloud observations also show an increase with decreasing distance to cloud edge. Possible causes include 3-D radiative effects, but also increased aerosol concentration or size near clouds as indicated by theory and suborbital observations.
4) Airborne and ground-based remote sensing of the aerosol-cloud boundary by means of sunphotometry is promising, may suffer from certain caveats, and should be supplemented by in situ measurement at cloud-level to increase its usefulness for testing MODIS retrievals of aerosols near clouds.
5) Next steps: estimate 3-D radiative effects for specific cloud/aerosol situations + run MODIS aerosol algorithm at smaller (pixel?) scale to compare to higher resolution suborbital observations.