Retrieval of AOD under Cloudy Conditions from Multispectral Aircraft Observations: Simulation Results

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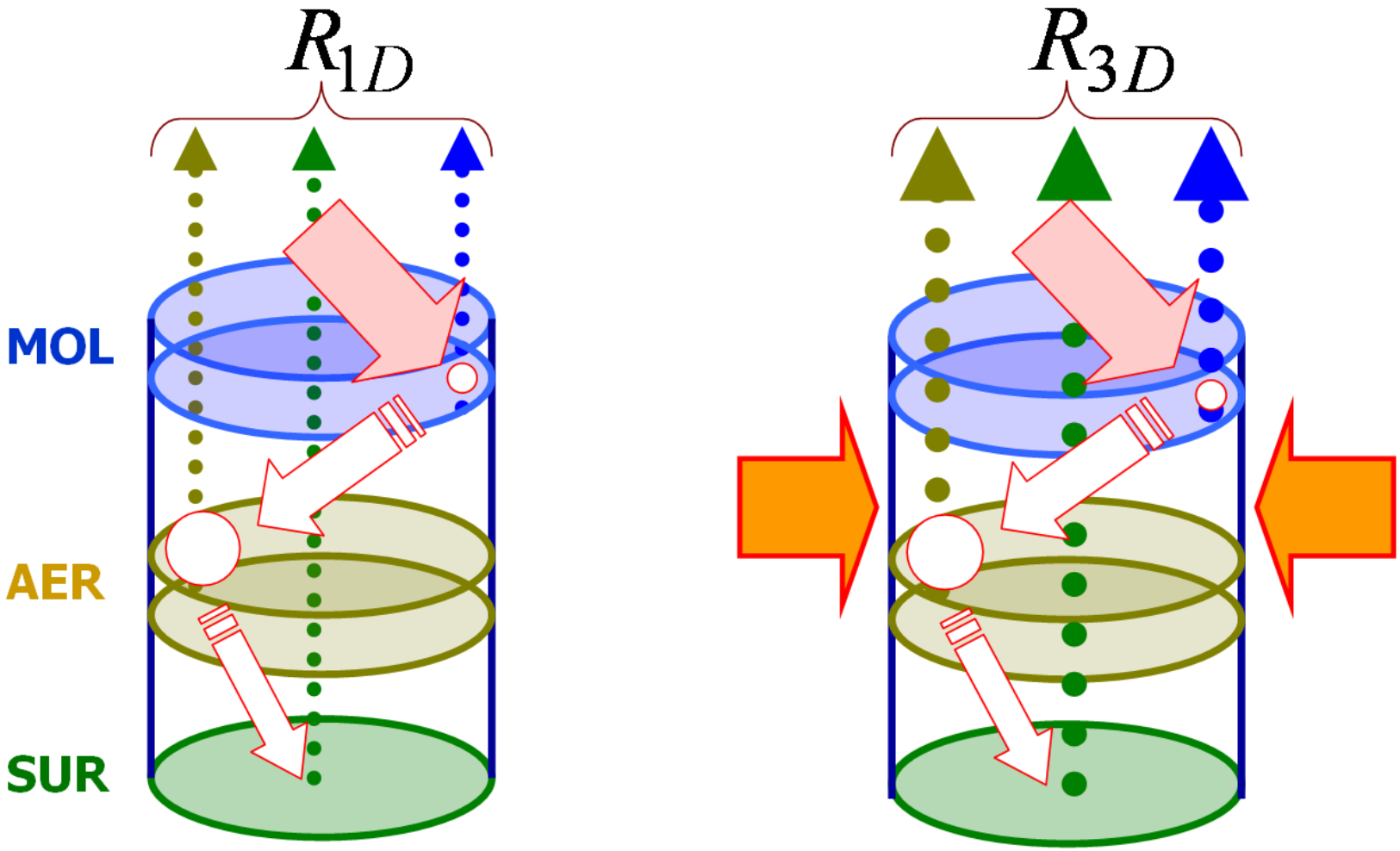
Background

- MODIS aerosol statistics obtained in clear patches of cloud fields may be biased (~140%) (Wen et al., 2007).
- This problem is due to large 3D cloud-induced enhancement (E).

* Wen, G., A. Marshak, R. Cahalan, L. Remer, and R. Kleidman (2007): *3D aerosol-cloud radiative interaction observed in collocated MODIS and ASTER images of cumulus cloud, JGR*

Enhancement



- Enhancement: $E = R_{3D} - R_{1D}$

Enhancement vs Reflectance

Recent studies (Wen et al, 2007) have shown:

- ✓ E and R_{1D} have similar spectral dependence
- ✓ E increases with *cloud optical depth* (*COD*).

- *COD* is almost spectrally independent

- Our Assumption: $E(\lambda) \sim \gamma R_{1D}(\lambda)$,

  parameter $\gamma = f(COD)$

Reflectance Ratio

$$\frac{R_{3D}(\lambda_1)}{R_{3D}(\lambda_2)} = \frac{R_{1D}(\lambda_1) + E(\lambda_1)}{R_{1D}(\lambda_2) + E(\lambda_2)}$$

$$E(\lambda) \approx \gamma R_{1D}(\lambda)$$

$$\frac{R_{3D}(\lambda_1)}{R_{3D}(\lambda_2)} \approx \frac{R_{1D}(\lambda_1)(1+\gamma)}{R_{1D}(\lambda_2)(1+\gamma)} \approx \frac{R_{1D}(\lambda_1)}{R_{1D}(\lambda_2)}$$

Objectives

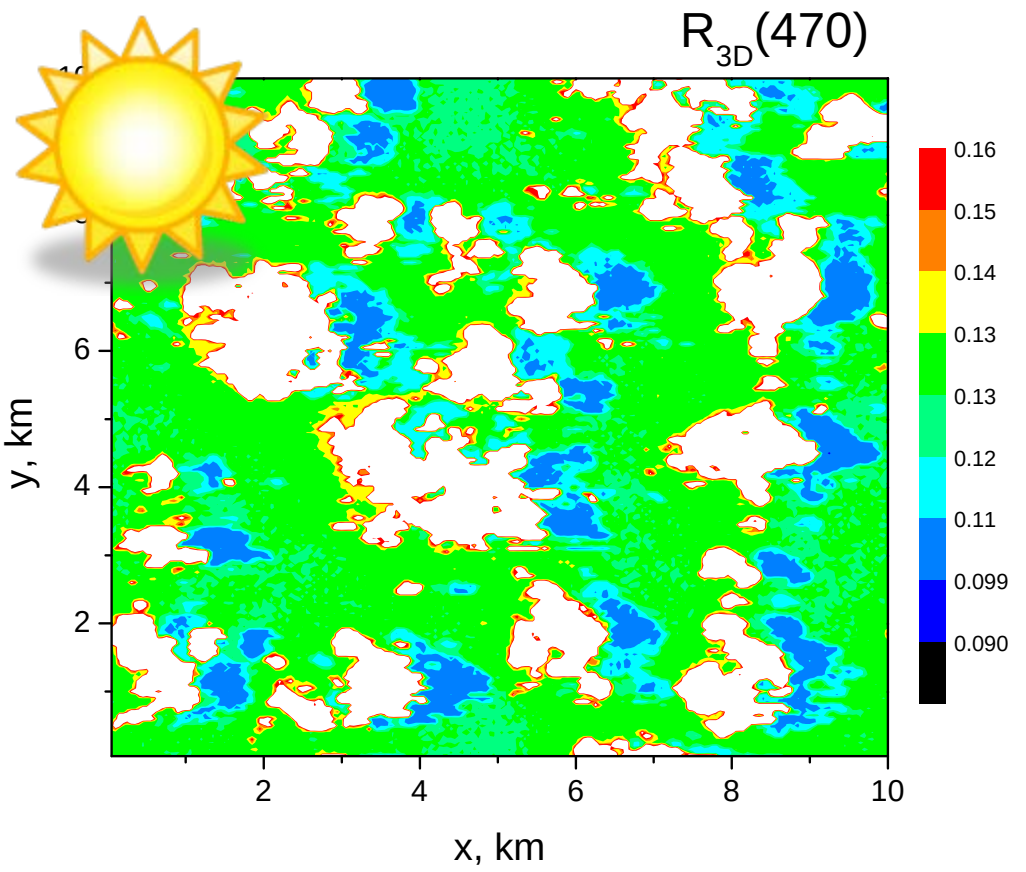
- *How sensitive is reflectance ratio (ρ) to 3D cloud effects?*
- *How can reflectance ratio be converted into aerosol optical depth (AOD)?*

Approach

- LES model

  Aerosol (3D spatial)
  Clouds (3D spatial)
  Size-resolved

  CHAPS/CLASIC

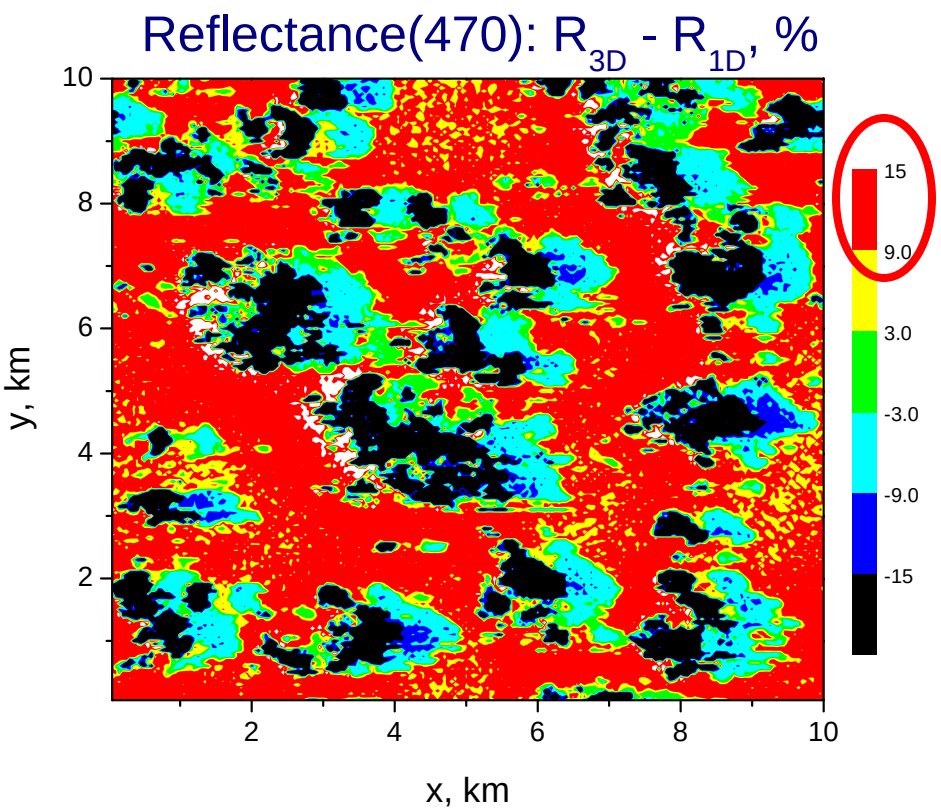


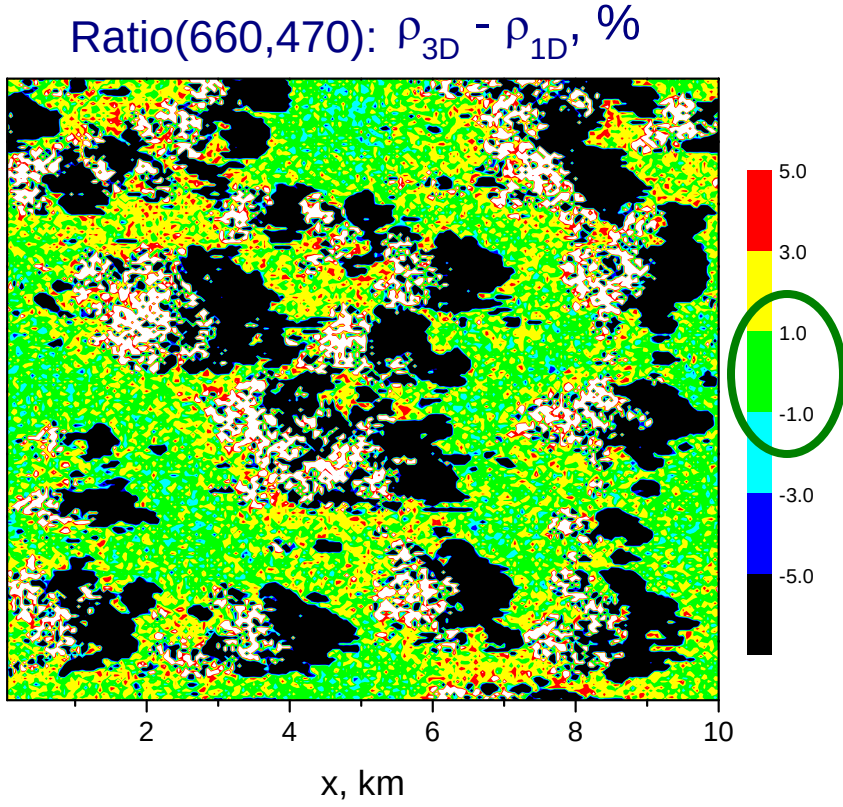
- RT Calculations

  Aircraft (MAS): 470, 660, 870 nm

*** MODIS Airborne Simulator (MAS)** mounted in the ER-2 NASA aircraft

Reflectance vs Ratio: 3D Effects





- Clear pixels (Wen et al., 2007): R_{3D}-R_{1D} ~ 10%
- Ratio is less sensitive to 3D effects: $\Delta\rho$ ~ 1%.

Reflectance Ratio vs AOD

$$\rho(\lambda_2;\lambda_1) = f(\tau_a(\lambda_2),\tau_a(\lambda_1))$$

$$\rho(\lambda_3;\lambda_1) = f(\tau_a(\lambda_3),\tau_a(\lambda_1))$$

Two knowns **Three unknowns**

Reflectance Ratio vs AOD

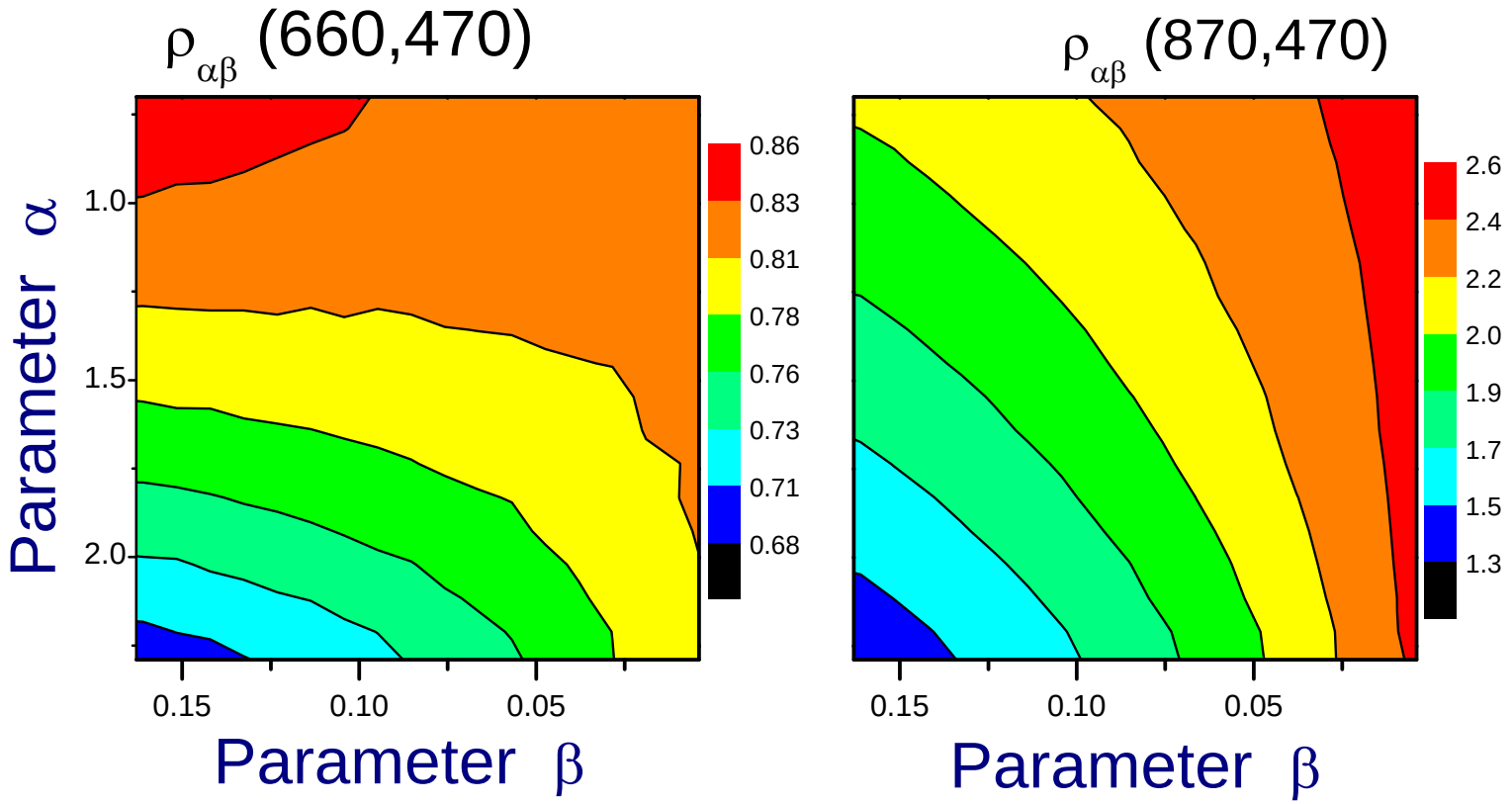
Assumption: $\tau_a(\lambda) = \beta \lambda^{-\alpha}$

$$\rho(\lambda_2;\lambda_1) = f_1(\alpha,\beta)$$

$$\rho(\lambda_3;\lambda_1) = f_2(\alpha,\beta)$$

Two knowns Two unknowns

Look-up Tables: 1D Ratio

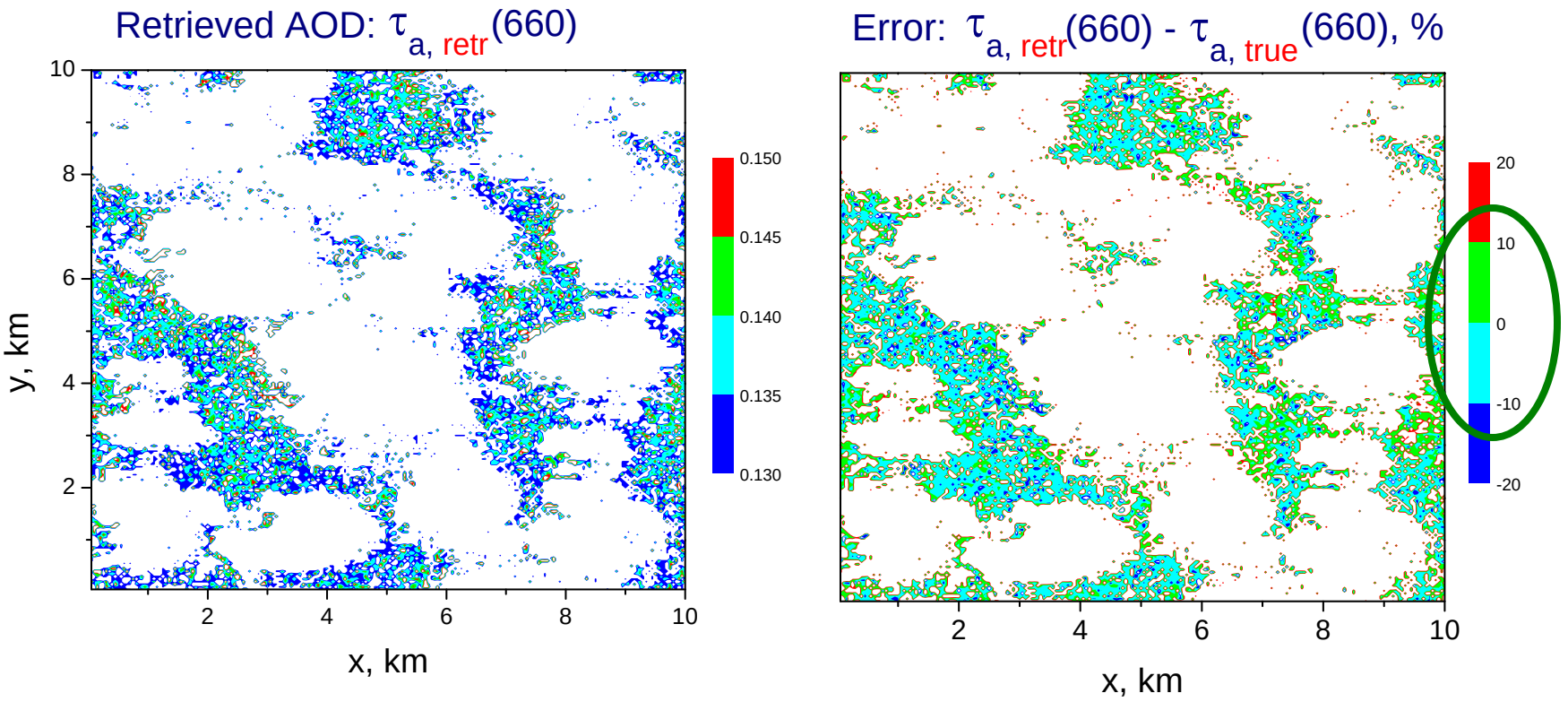


- Isolines of ρ values are nearly orthogonal.
- A unique solution of (α,β) can be obtained.

AOD Retrieval: Simulation

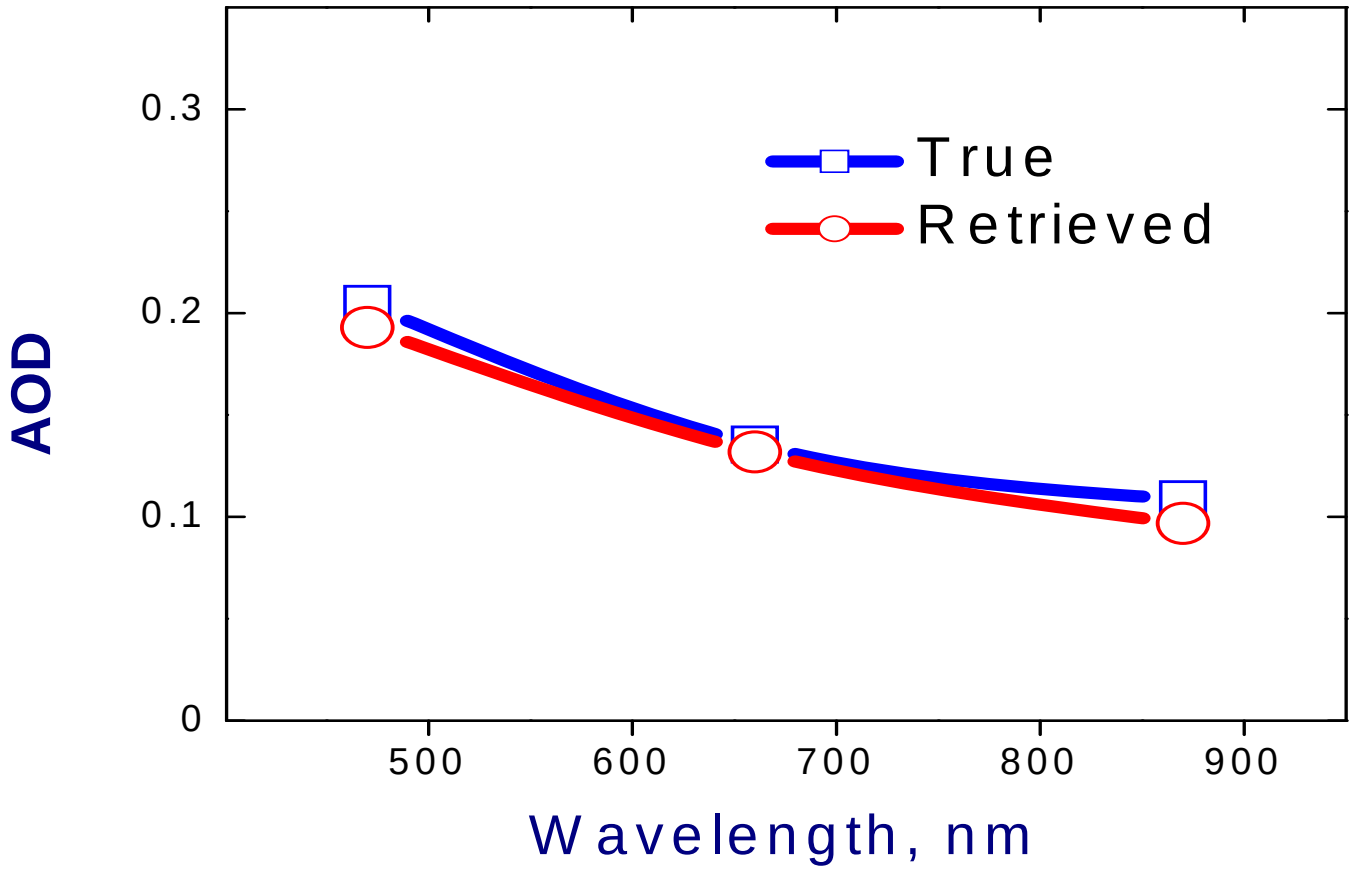
- Assume calculated 3D reflectance ratios as “observations”
- Apply created 1D Look-up Tables
- Retrieve two parameters (α,β), AOD
- Compare retrieved and true AOD values

AOD Retrieval: Results



- For majority of clear pixels difference between retrieved and true values is within 15%.

AOD Retrieval: Results



- Domain-averaged difference is ~ 5%.

Conclusion

- **Reflectance ratios** are less sensitive to *3D cloud effects* than reflectances themselves.

- **Reflectance ratios** can be converted successfully into AOD *in vicinity of clouds*.

* Kassianov and Ovtchinnikov, 2008: *On Reflectance Ratios and AOD Retrieval in Presence of Cumulus Clouds* , GRL (accepted)

Future Activities

- Perform sensitivity studies:

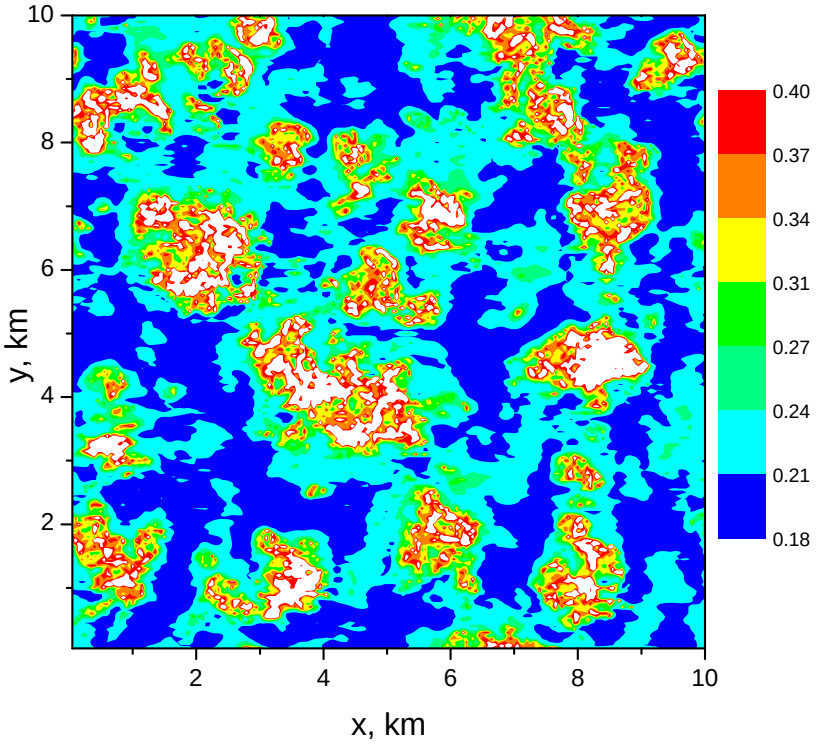
  Observational conditions (e.g., SZA)
  Wavelengths (e.g., bright surface)
  Aerosol and **surface** types

- Apply AOD retrieval (CHAPS/CLASIC,...)

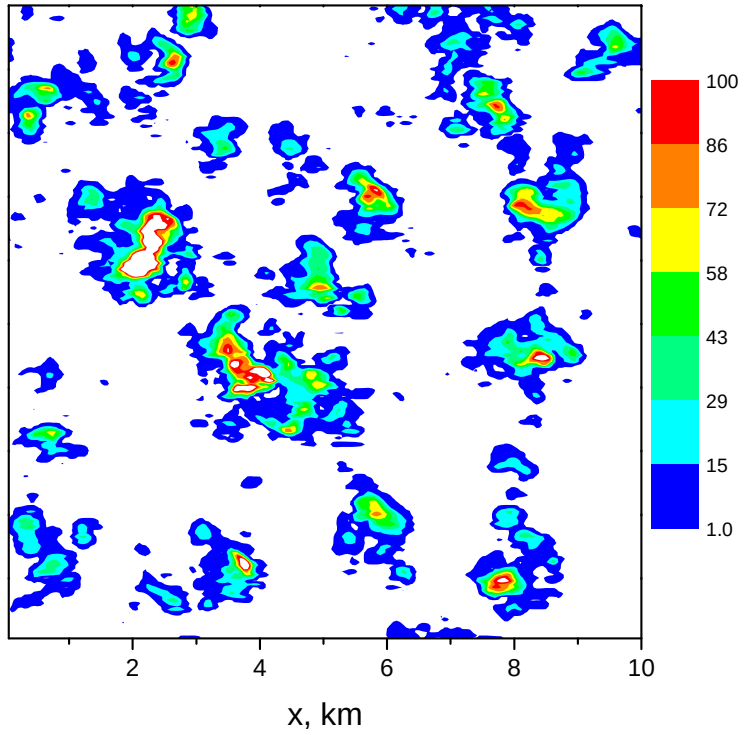

Thanks !

LES Output (Example)

Aerosol Optical Depth (470 nm)

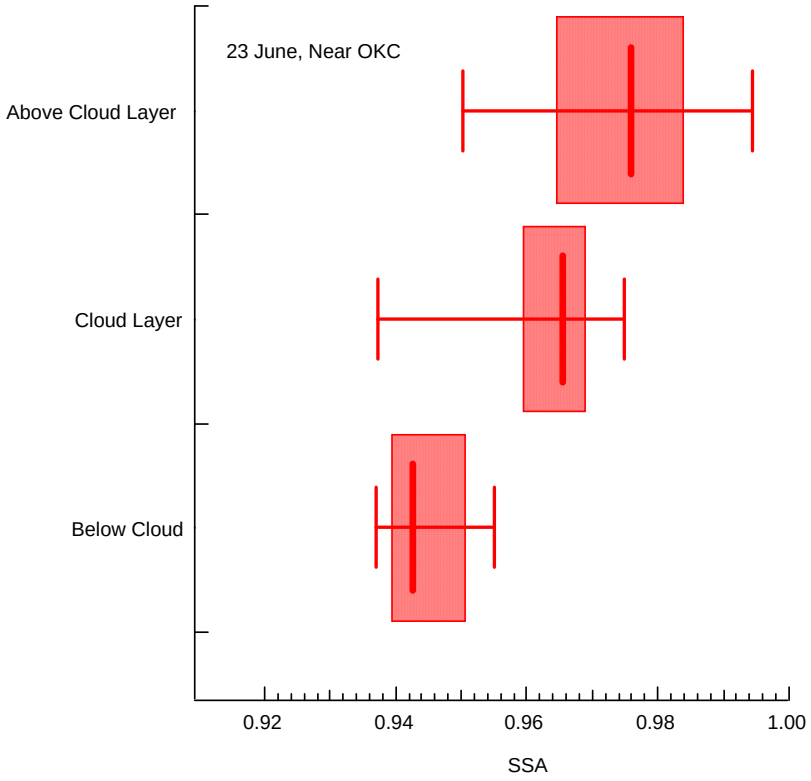


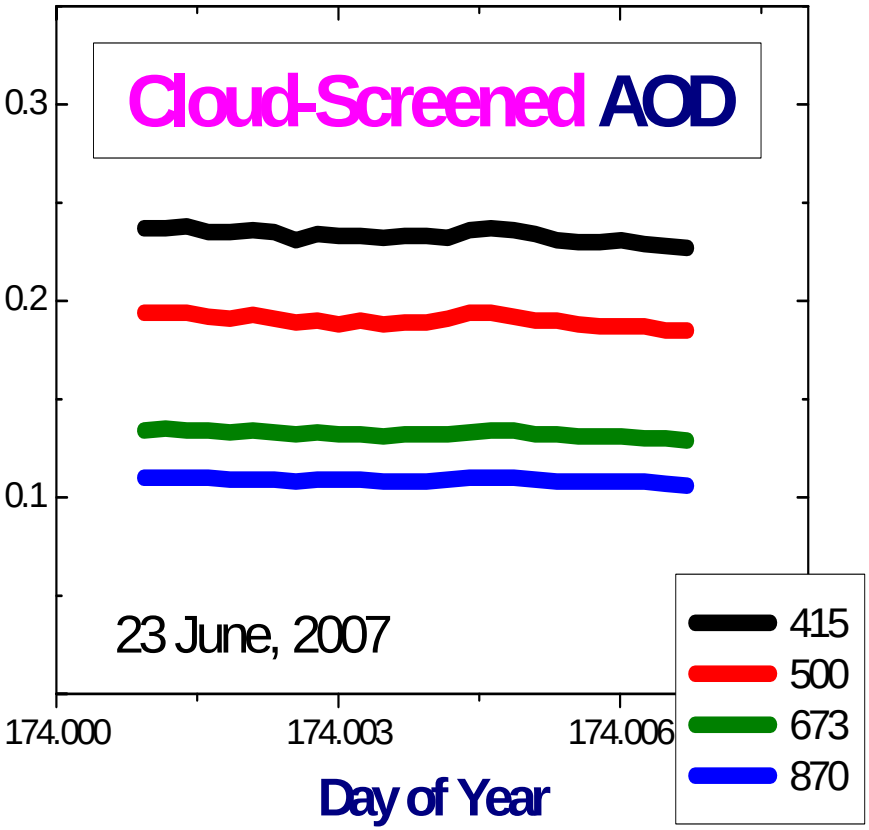
Cloud Optical Depth (470 nm)



- Both **AOD** and **COD** exhibit large spatial variability
- Variations of **AOD** and **COD** are strongly correlated

CLASIC/CHAPS: Aerosol





- SSA from nephelometer and PSAP (left)
- Cloud-screened MFRSR-derived AOD (right)