Aerosol Induced Changes in Continental Clouds Properties: Aerosol-Cloud-Interaction

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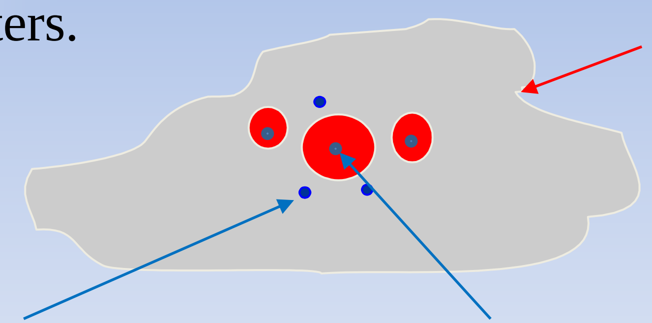
Cloud formation

Clouds form in the atmosphere when water vapor is supersaturated.

Water vapor supersaturation is attained by cooling:
Through expansion in updraft regions and radiative cooling

Cloud droplets form from atmospheric aerosol. This process is known as *activation*.
Aerosols that act as a site for water vapor for condensation are called *cloud condensation nuclei* (CCN).
We define here; The subset of atmospheric aerosol (size > 80 nm), called Accumulation mode aerosol (N_{acc}) can be taken as a proxy for CCN (Lihavainen, 2010). N_{acc} are important for activation alongwith other meteorological parameters.



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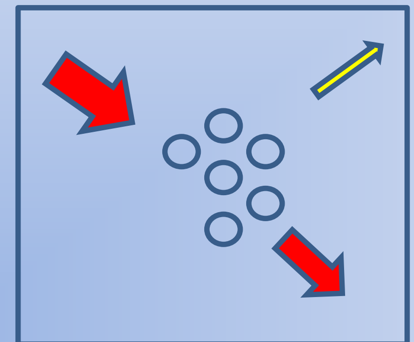
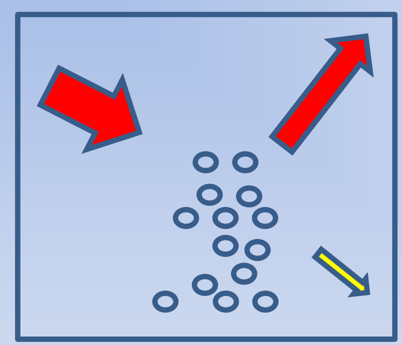
Aerosol Direct and Indirect effect

- Direct effect: Scatter solar and terrestrial radiation
- Indirect effect: Aerosol acts as a Cloud Condensation Nuclii (CCN)
- Increase in aerosol
  - Increases cloud droplet number concentration (N_d), decreases cloud droplet size keeping LWC constant (1st indirect effect [*Twomey effect, 1977*])
  - increases cloud‘s life time, (2nd indirect effect [*Albrecht, 1989*])
- Hence affect global radiation



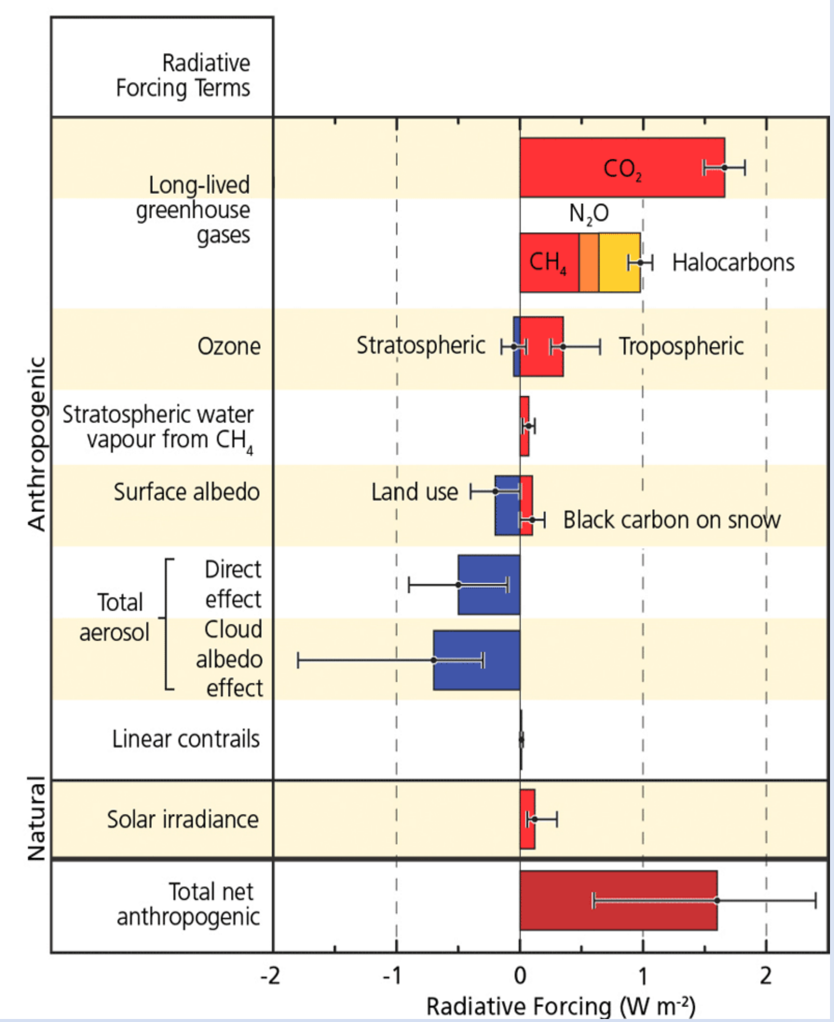
Clean cloud: Large cloud droplet, Low albedo, Efficient precipitation.



Polluted cloud: Small cloud droplet, High albedo, Suppressed precipitation

Why Aerosol Cloud Interaction?

- ICCP report, 2007
- Reducing stratocumulus R_{eff} from 10 μm to 8 μm balance the warming by CO_2 doubling, Slingo (1990).
- Cloud radiative forcing ≈ –15 Wm^{-2} (cooling effect), Ramanathan, 1989. Forcing by doubling atmospheric CO_2 concentration ≈ 4 Wm^{-2} (warming effect) (IPCC, 1994)
- ACI is complex and poorly understood, further study is needed



IPCC, 2007

What we measure?

- To make our contribution in estimating global radiation budget and climate change using regional measurements from Puijo station,
- To add an extra spot (Puijo) in the research field for measurement and comparison of ACI to Satellite data

we are interested in;

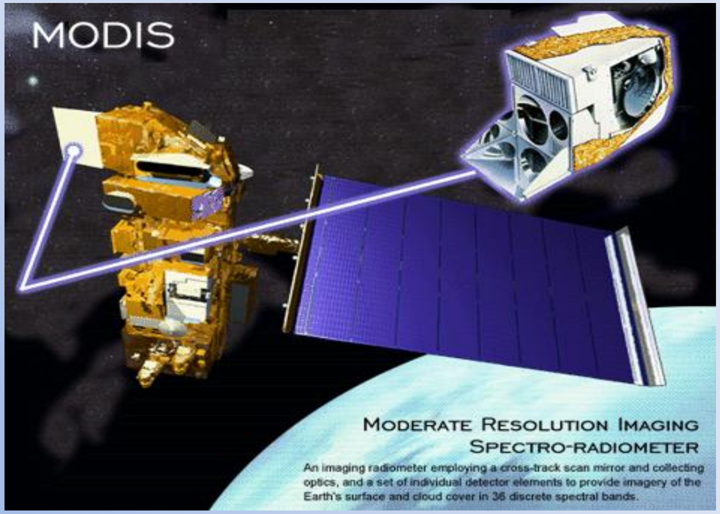
- Aerosol-Cloud-Interaction (ACI)
- Cloud droplet effective radii (*Reff*)
- Cloud Optical Thickness (COT)
- Cloud droplet number concentration (N_d)
- Comparison of different approaches (In-situ, Satellite)

Approaches
1-Ground based in-situ measurement (Puijo)

- **Puijo data**
  - ✓ DMPS (DMA+CPC) data for 80nm>size>800nm (*Nacc*)
  - ✓ CDP data in accordance to MODIS available data
  - ✓ Ceilometer (62.892N 27.633E) data (boundary, single cloud layer)
  - ✓ Direct (< 224m hight of Puijo tower)
  - ✓ Above Puijo (< 800m asl)
  - ✓ Puijo weather data (rain intensity < 0.2mm/h, visibility < 200m)

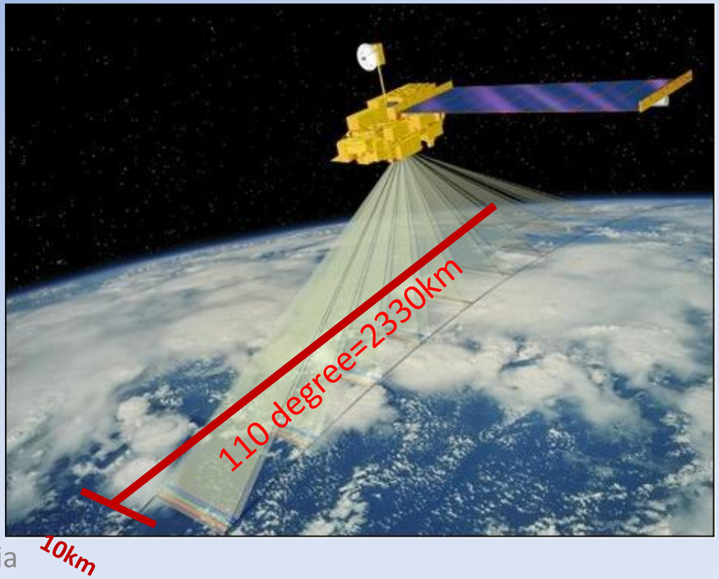
2-MODIS

- MODIS on board Terra and Aqua
- Orbit 705 km, Polar sunsynchronous,
  - ✓ Swath width 2330km, FOV 110º, 1354 pixels in cross-track
  - ✓ Swath length 10km, 10 pixel along-track



- MODIS 36 channel (0.4 -14.5) µm scanning spectroradiometer
- 1-visible (0.645µm)
- 3-NIR (1.64, 2.13, 3.75) µm

4 bands for day time shortwave IR cloud retrieval over land (COT, Rff, LWP)



Bands used from MODIS

- Reff: 2.1µm and 3.7 µm
- COT: 0.64 µm and 0.86
- Over ocean 0.64 is replaced by 0.858 µm

- Other bands (e.g 8.55, 11.03, 12.02, 13.335, 13.935 and 14.235) are used for cloud fraction and cloud top properties (cloud top temperature, cloud top pressure, etc.)

Table 1. Spectral characteristics, spatial resolution, saturation reflection function (at θ_0 = 22.5°), saturation brightness temperature, and principal purposes of cloud bands used on MODIS.

Band	λ (µm)	Δλ (µm)	Ground resolution (m)	R_{max}	T_{max} (K)	Atmospheric Purpose
1	0.645	0.050	250	1.43		Cloud optical thickness over land
2	0.858	0.035	250	0.96		Cloud optical thickness over ocean
5	1.240	0.020	500	0.78		Cloud optical thickness over snow & sea ice surfaces
6	1.640	0.025	500	1.02		Snow/cloud discrimination; thermodynamic phase
7	2.130	0.050	500	0.81		Cloud effective radius
20	3.750	0.180	1000		335	Cloud effective radius; Cloud/surface temperature
31	11.030	0.500	1000		400	Thermal correction

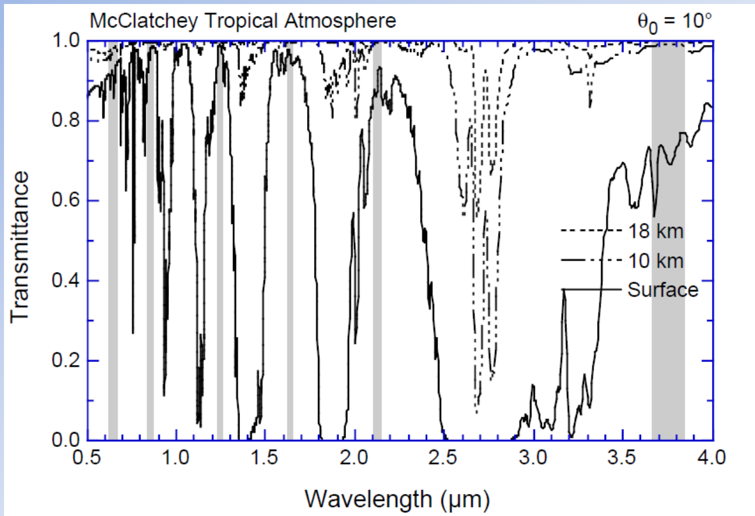


Figure 2. Spectral characteristics of six MODIS bands, centered at 0.65, 0.86, 1.24, 1.64, 2.13, and 3.75 µm, used for cloud property detection. The atmospheric transmittances are calculated from LOWTRAN 7 at 18 km, 10 km and at the surface for the McClatchey tropical atmosphere at 10° solar zenith angle.

King et al 1997 , Platnick et al 1997

MODIS overpass

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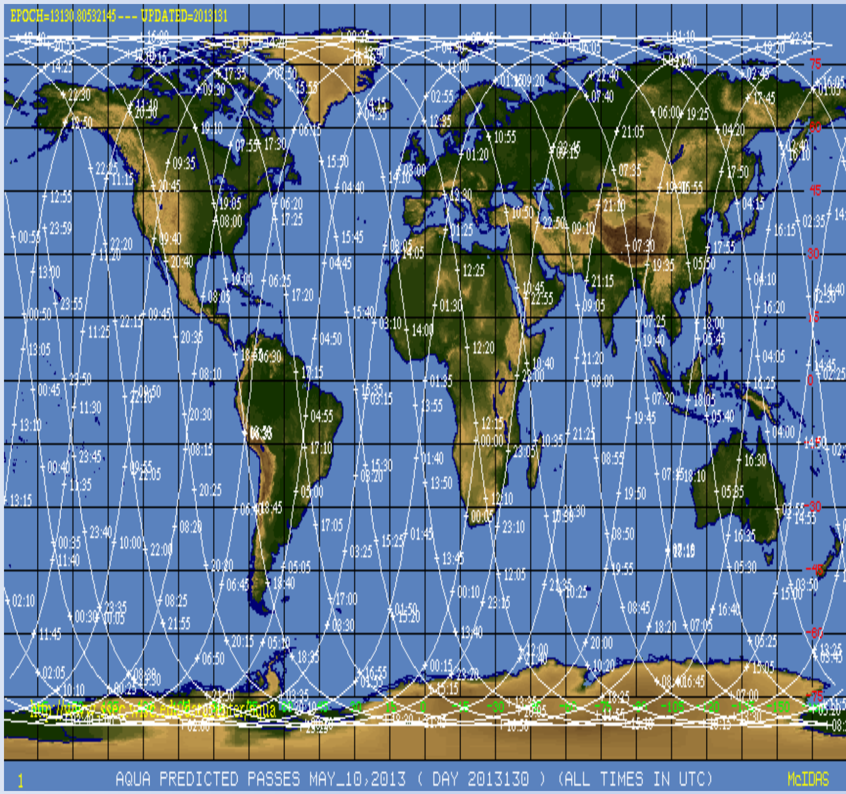
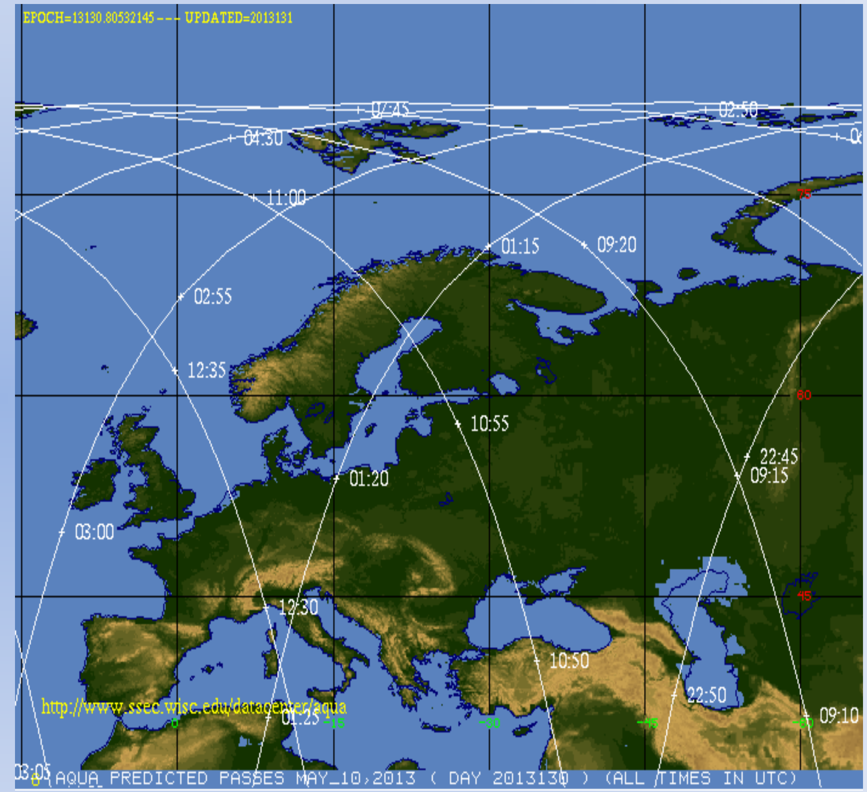
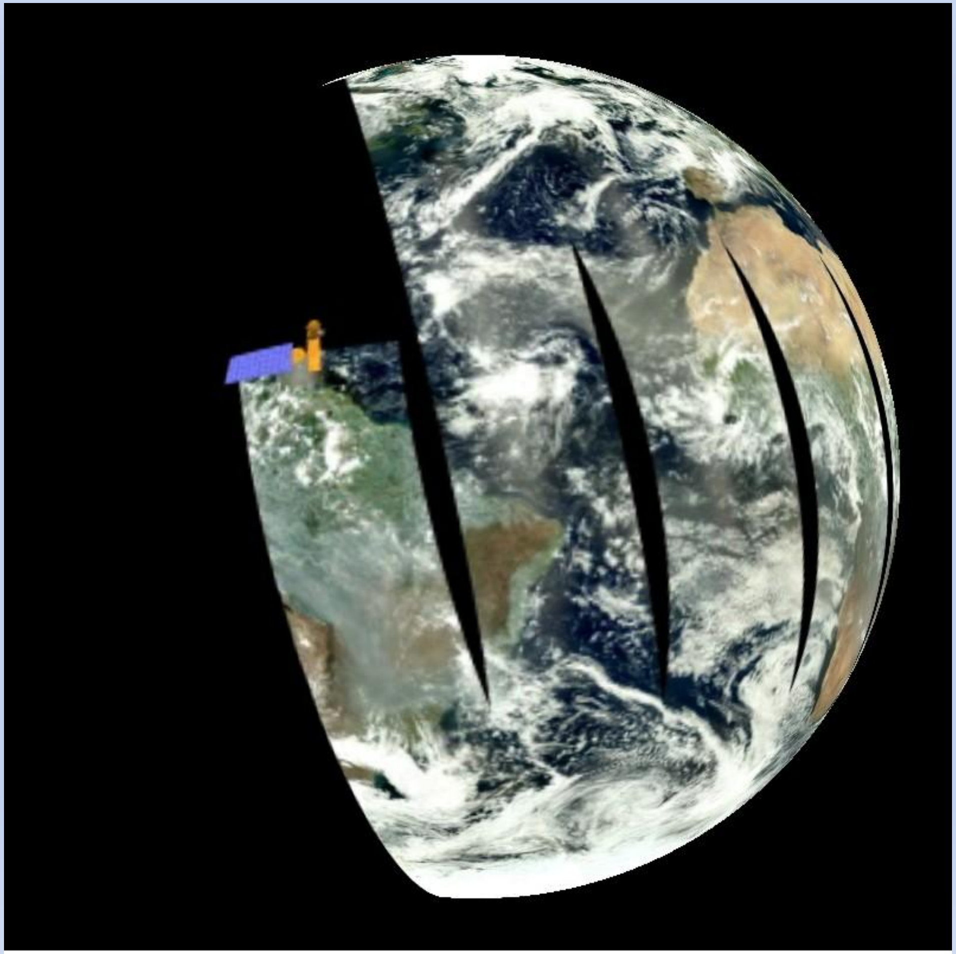
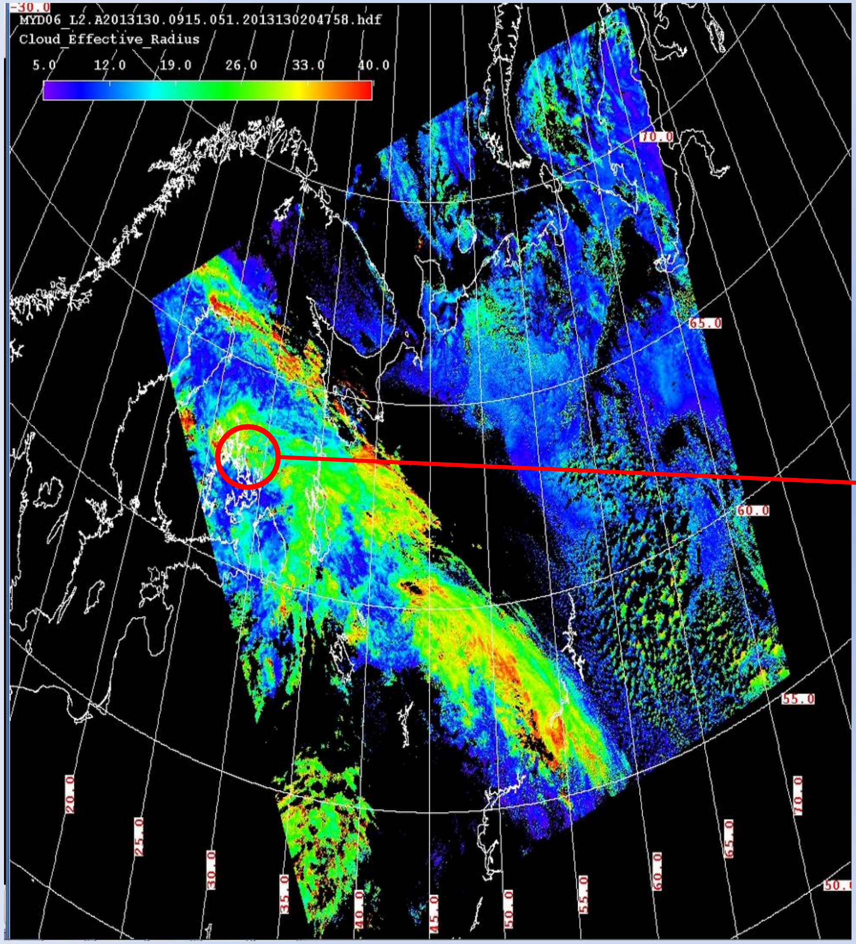




http://www.ssec.wisc.edu




MYD06_L2.A2013130.0915.051.2013130204758.hdf
Cloud_Effective_Radius
5.0 12.0 19.0 26.0 33.0 40.0
70.0
65.0
60.0
55.0
50.0
20.0
25.0
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35.0
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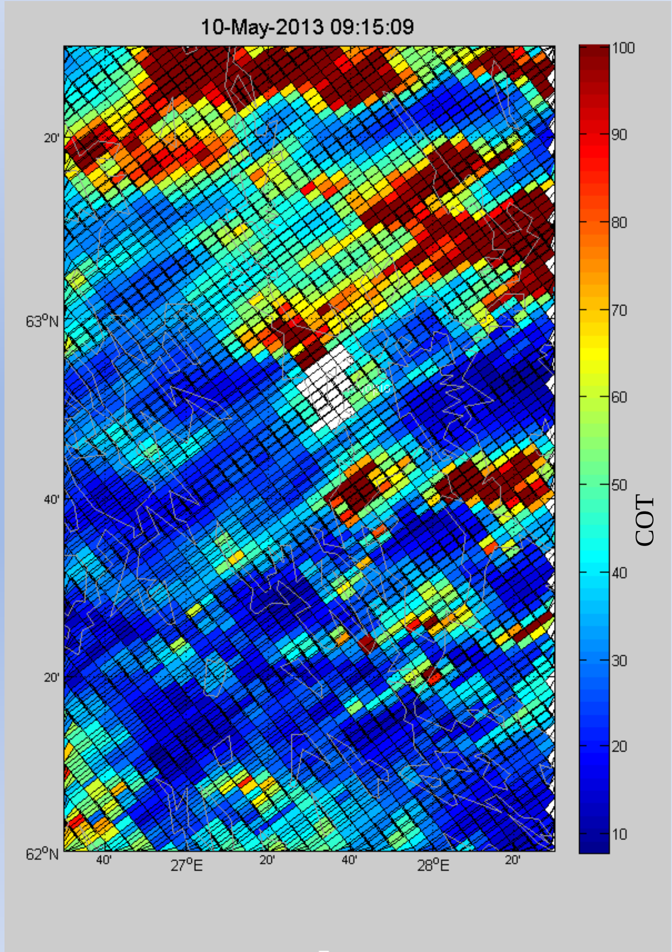
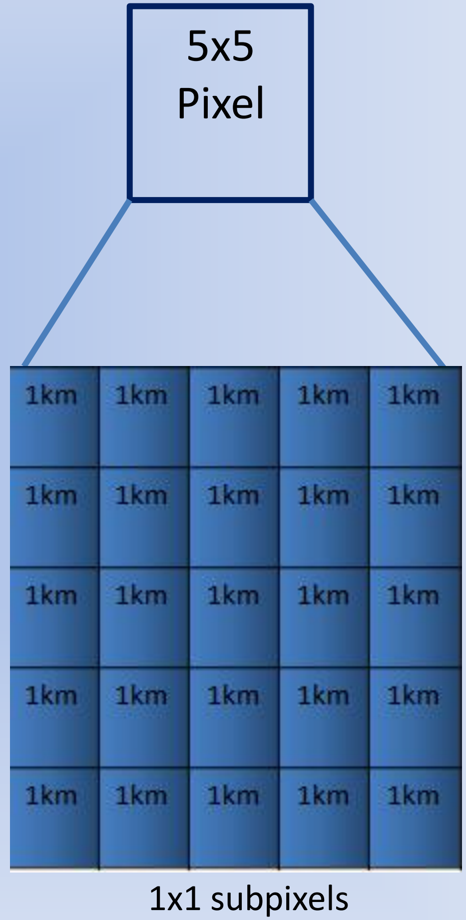
60.0
65.0
70.0

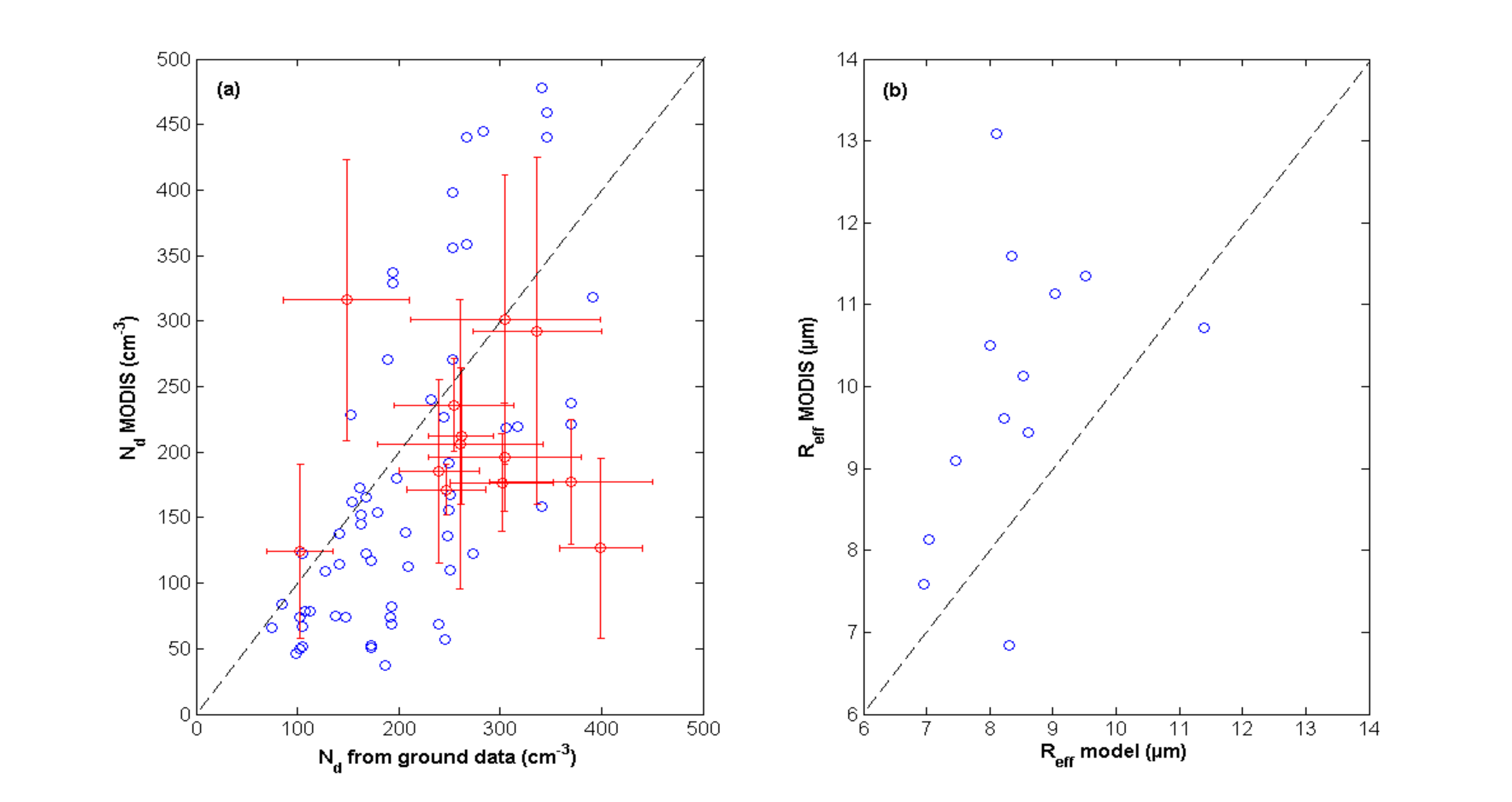

10-May-2013 09:15:09
20'
63°N
40'
20'
62°N
40'
27°E
20'
40'
28°E
20'
100
90
80
70
60
50
40
30
20
10
COT

MODIS (1x1km)

- 5x5 km pixel consists of 25 subpixels.
- 1 sq.km (1x1 km) retrieval→ subpixel data
- → high confidence levels quality assurance data from 1 sq.km
- → 5 sq.km (5x5 km)
- → Centered around Puijo



- Direct: Correlation coefficient -0.07 BY CHANCE ?? YES (with 95 % confidence limits ranging from -0.6 to +0.5), 95% confidence -> more data -> increased correlation.
- Mean *Nd* :In-situ 271 cm^{-3}, MODIS 209 cm^{-3}.
- Different spatial and temporal averages does not affect/improve the comparison
- Estimated: Correlation 0.65, but with 95 % confidence limits are 0.47 and 0.78).



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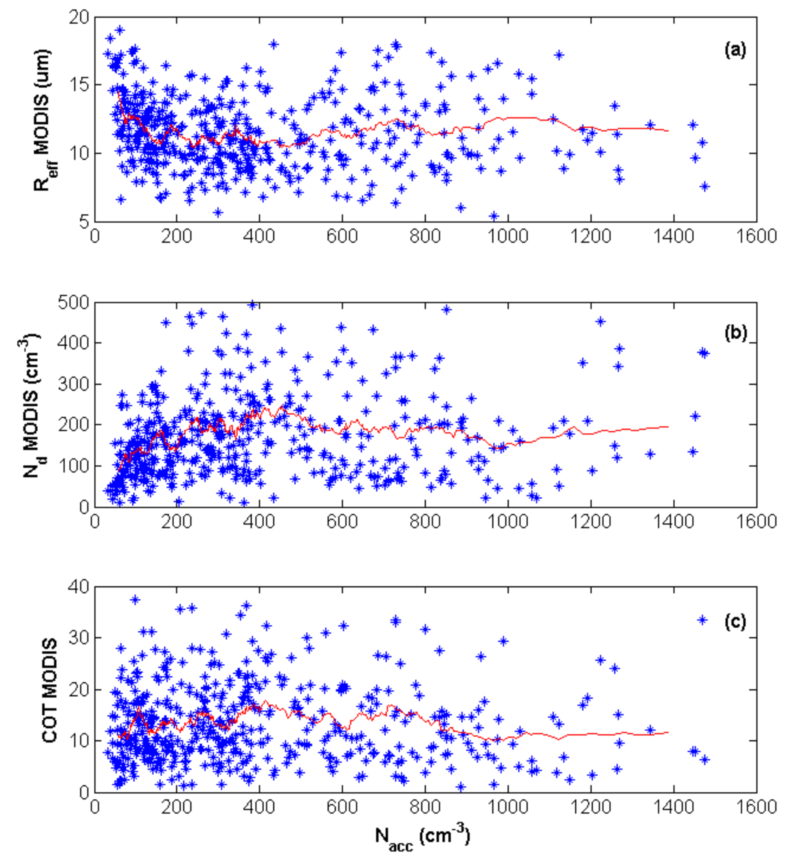
- Spearman correlation is 0.63 for N_{acc} less than 400 cm^{-3}
- MODIS: ACI value 0.14 ($ACI=0.33*dln(N_d)/dln(N_{acc})$)
- In-situ: ACI value 0.16
- Long term in-situ measured N_d 217 cm^{-3}
- MODIS retrieved N_d is 171 cm^{-3}



OCAA 2013, Slovakia

Ahmad et al., 2013

Questions

- Satellite for a single point observations
- Aerosol induced changes in cloud properties keeping meteorological parameters constant to understand the relation between aerosol and cloud properties.

Thanks

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- http://sos.noaa.gov/Datasets/dataset.php?id=34