Investigating the relationships between aerosol and cloud properties in Aqua MODIS data

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Introduction

- Microphysical and dynamical interactions between clouds and aerosols are associated with some of the largest uncertainties in projections of future climate.
- Several studies investigating correlations between cloud and aerosol properties have been published in recent years. However, much uncertainty remains and further work needs to done in order to quantify the physical reasons for these observations.
- We use MODIS and ATSR data to investigate some of these cloud-aerosol correlations, and how they vary between different regions.

Acronyms: aerosol and cloud properties

- Aerosol optical depth (AOD) is a measure of the total extinction due to aerosol in an atmospheric column.
- Liquid cloud effective radius (CER_{liquid}) is a retrieved estimate of the size of the droplets near the top of liquid water clouds.
- Cloud fraction (CF) gives the fractional cover of all clouds (liquid and ice) in a given region.
- Cloud top pressure (CTP) is the average pressure at the top of all clouds (liquid and ice) in a given region.

Previous studies

- Using MODIS gridded daily mean data, Kaufman et al (2005) find a negative correlation between CER_{liquid} and AOD for stratiform liquid clouds over North Atlantic.
- During a similar study of convective clouds, Koren et al (2005) find a negative correlation between CTP and AOD and a positive correlation between CF and AOD.
- Quaas et al (2008) calculate linear regression slopes of ln(droplet number concentration) vs ln(AOD) for different regions and seasons. They generally find that higher AODs are associated with a higher droplet concentration.
- Bulgin et al (2008) use ATSR-2 data to calculate the linear regression slopes of ln(CER_{liquid}) vs ln(AOD) and the corresponding correlations for different regions and seasons. They generally find negative CER_{liquid}–AOD correlations. However, positive correlations are also often observed.

Method

- We use 6 years (2003–2008) of the 1°×1° gridded daily mean data product from the MODIS instrument onboard the Aqua satellite. Aqua has a local overpass time of 1330.
- For each 1°×1° grid box, we calculate linear Pearson correlation coefficients and linear regression slopes between the natural logarithms of different cloud properties and AOD. Figure 2 shows CER_{liquid} vs AOD for one grid box.
- We make global maps of these correlations and regressions.

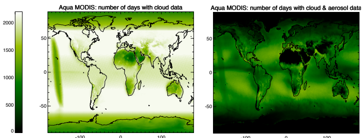

Figure 1: Number of days of available data.

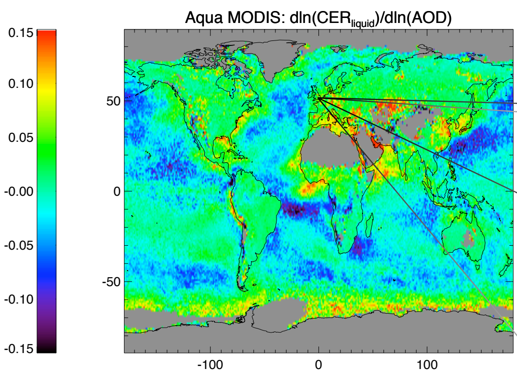

Figure 3: Linear regression slopes of ln(CER_{liquid}) vs ln(AOD) for each 1°×1° grid box using six years (2003–2008) of MODIS data.

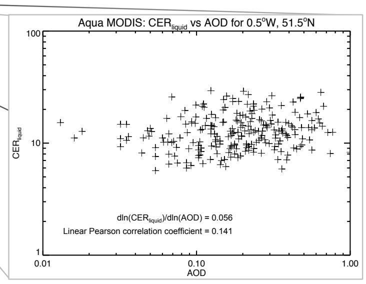

Figure 2: CER_{liquid} vs AOD for the 1°×1° grid box centred on 0.5°W and 51.5°N (covering Reading).

Cloud cover and height

- Figure 5 shows that for most of the world, higher aerosol conditions are associated with greater cloud cover.
- Figure 6 shows that, in general, higher aerosol conditions are associated with higher clouds.
- However, these observed correlations are not necessarily due to microphysical effects. They may be due to cloud flagging errors, retrieval errors, seasonal factors or synoptic effects.
- Figure 7 shows a strong and globally persistent negative correlation between CF and CTP, showing that higher cloud tops generally correspond to greater total cloud cover.

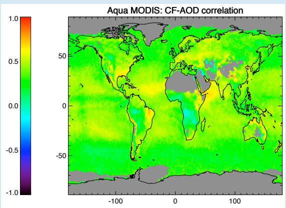

Figure 5: Linear Pearson correlation coefficient between CF and AOD.

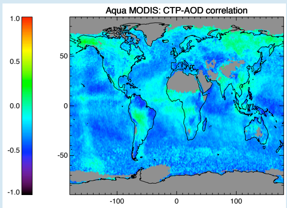

Figure 6: Linear Pearson correlation coefficient between CTP and AOD.

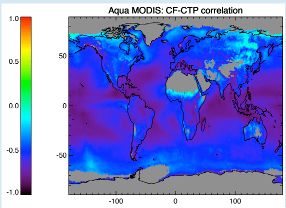

Figure 7: Linear Pearson correlation coefficient between CF and CTP.

Reliability of CER_{liquid} data

- As can been seen in Figure 4, MODIS and ATSR CER_{liquid} retrievals do not agree.

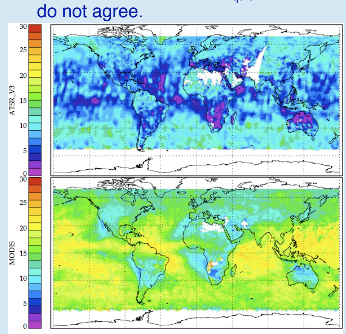

Figure 4: Comparison between monthly mean CER_{liquid} retrievals for ATSR (top; work in progress) and MODIS (bottom) for July 2000. *(Courtesy of C. Poulson.)*

- Bréon and Doutriaux-Boucher (2005) find a poor correlation between MODIS and POLDER CER_{liquid} over land, with a better correlation over the ocean, although MODIS CER_{liquid} is generally higher. POLDER is limited to homogeneous cloud fields.
- Marshak et al (2006) suggest that the MODIS CER_{liquid} retrieval may not be reliable for inhomogeneous cloud fields.

Conclusions

- The relationships between cloud and aerosol properties are complicated, and there is potential for over-simplification to occur if large regions are averaged over.
- Using the analysis presented here, it is very difficult to identify microphysical, seasonal, synoptic and retrieval-related effects.
- We intend to identify seasonal factors in the near future, before investigating synoptics.

References

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