Cloud Regimes as a Tool for Systematic Study of Various Aerosol-cloud-precipitation Interactions

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Our thinking

• Need to understand effects of aerosols on clouds and precipitation and eventually on Earth’s Radiation Budget
• Problem poses obvious observational challenges
• How to separate aerosol from all other effects?
• Breaking down the analysis by “regime” (group together similar conditions) may help
• But how do we define regimes?
  – Exploiting cloud appearance (from passive obs) is a starting point
  – This poses some constraint on environmental conditions
  – Additional constraints can be imposed
• So we proceed with a “cloud regime” (CR) analysis
  – Our CRs are based on MODIS
  – You may also know ISCCP “Weather States”
The 12 MODIS Collection 6 CRs
Where the CRs occur
The full picture
Dataset and methodology

• 12 years of Aqua-Terra L-3 daily (D3) 1° data
  – Collection 6
• Joint histograms of CTP-TAU
• MODIS CRs from $k$-means clustering of CTP-TAU joints
• Aerosol Optical Depth (AOD)
  – We calculate seasonal AOD distributions and perform compositing at the vigintile level (20-bin distribution) of cloud properties and precipitation for each CR separately (Terra CR=Aqua CR)
  – We often focus on the upper (3Q, “high” aerosol) and lower (1Q, “low” aerosol) quartile and perform statistical significance test
  – Two ways to build AOD seasonal distributions: (1) for each gridcell (stronger constraint); (2) for each CR (weaker constraint)
• Precipitation data: GPCP-1DD
• Land/ocean separation illuminating
Sampling issues
(how to build AOD distributions)
1) \( AOD = \frac{(Aqua\ AOD + Terra\ AOD)}{2} \).

2) \( AOD = Aqua\ AOD \quad OR \quad AOD = Terra\ AOD \)

3) \( AOD = \frac{(Aqua\ AOD_1 + Aqua\ AOD_2 + Terra\ AOD_1)}{3} \).
Comparison of two AOD sampling options (CR3)

AOD distribution defined PER CR

AOD distribution defined PER GRIDCELL

1Q AOD

1Q AOD
Precipitation
Precipitation comparison (RR>0) two sampling methods

3Q/1Q AOD defined by per CR per Season

1Q

3Q

3Q/1Q AOD defined by per Grid per Season

1Q

3Q

GPCP Precipitation (mm/day) with 1Q AOD

GPCP Precipitation (mm/day) with 3Q AOD

CR1
CR2
CR3
CR6
CR7
CR8
CR9
CR10
CR11
CR12

CR1
CR2
CR3
CR4
CR5
CR6
CR7
CR8
CR9
CR10
CR11
CR12
Precipitation (RR>0) comparison (Land-Ocean)

**Global**

**Ocean**

**Land**
Precipitation (RR>0) vs AOD percentile

- AOD distribution (%)
  - 2
  - 4
  - 6
  - 8

- GPCP Precipitation (mm/day)
  - 0
  - 5
  - 10
  - 15
  - 20
  - 25
  - 30
  - 35
  - 40
  - 45
  - 50
  - 55
  - 60
  - 65
  - 70
  - 75
  - 80
  - 85
  - 90
  - 95
  - 100

- CR1
- CR2
- CR3
- CR4
- CR5
- CR6
- CR7
- CR8
- CR9
- CR10
- CR11
- CR12
Cloud Properties
Cloud fraction

Red=meets expectations

Global

Ocean

Land
Cloud Top Pressure

(Gryspeerdt et al. 2014)
Cloud optical thickness

Red=meets expectations
Cloud effective radius

Blue=meets expectations

Global

Ocean

Land
Summary and parting thoughts

- We propose that Aerosol-Cloud-Precipitation relationships be examined on a “cloud regime” basis
  - This helps us examine aerosol influence under more “similar” conditions
- Even then, the outcomes depend on how one samples AOD distributions (weaker or stronger constraints on meteorology)
- Most times, cloud property and precipitation differences between low and high aerosol loadings are small (albeit statistically significant)
  - But not always consistent with expectations (optical thickness, low cloud precip)
  - Enhancement of precipitation for most CRs for large AOD
- Important: our analysis cannot distinguish how AOD retrievals biases vary due to cloud presence within or across CRs
- Also working with TMPA precip (forthcoming) hoping to resolve more details (e.g. morning/afternoon contrasts)
CR thermodynamic phase

Cloud fraction (%)

Liquid cloud fraction
Ice cloud fraction
Total cloud fraction


NASA
CR cloud type breakdown per CloudSat
Note that the Y-axis scale is not linear and different for CR2.
Ocean

Land
Ocean

Land

Note that the Y-axis scale is not linear and different for CR2.
MODIS Cloud Regime RFO (%)
Scatter plot comparing Latitudinally-weighted mean precipitation rate (including zero precipitation) for upper 3q AOD and lower 1q AOD. The horizontal and vertical error bars indicate one fifth of the interquartile range of the distributions used to calculate the composite means; distance from median to 25% percentile is represented by the error bars below and to the left of the symbol while that to the 75% percentile by the error bar above and to the right. All the values are statistically significant with 95% confidence except CR2 (LAND).

(Global Ocean Land)

MYD CR = MOD CR + daily grid new AOD + daily mean GPCP
Assigned 3Q AOD
Assigned 1Q AOD
Latitudinally-weighted Mean values of AOD assigned to 3q and 1q (per season per grid, what we used GPCP analysis) for each CR.

Red line : 3Q
Blue line : 1Q
Diamond : mean of AOD.