

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

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Acknowledgements: NASA's "The Science of Aqua and Terra" and "Modeling Analysis and Prediction (MAP)" programs

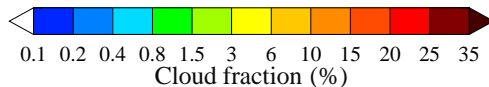
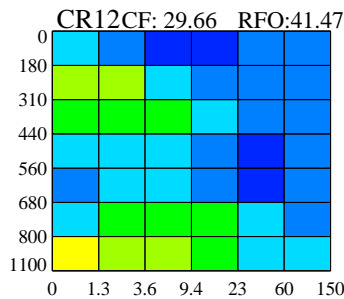
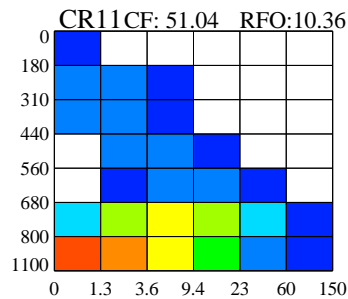
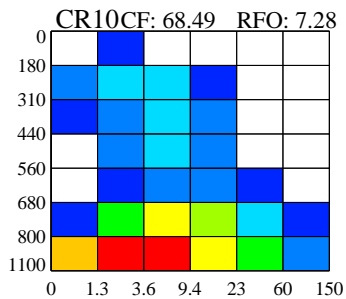
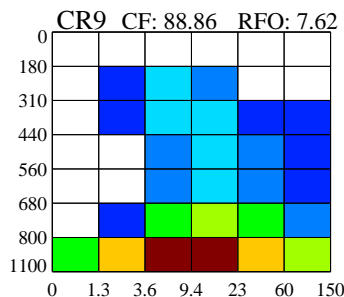
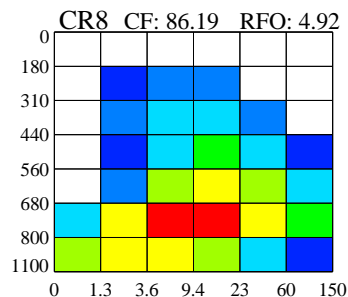
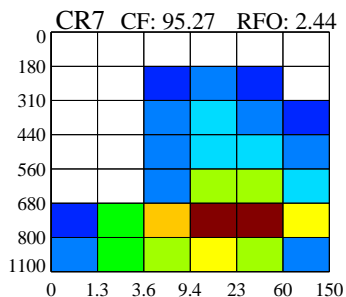
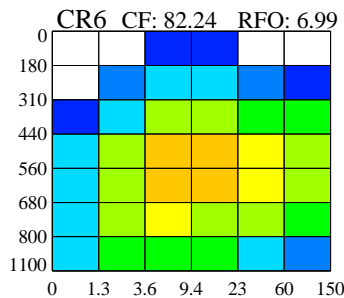
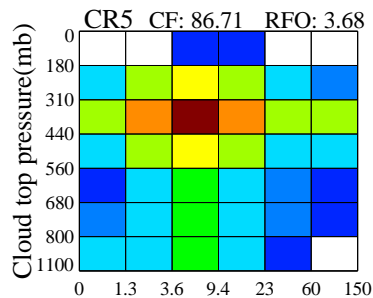
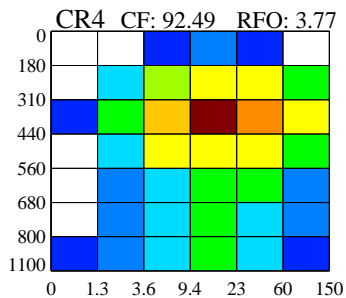
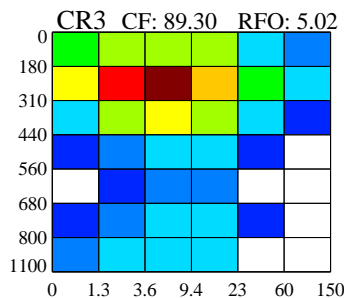
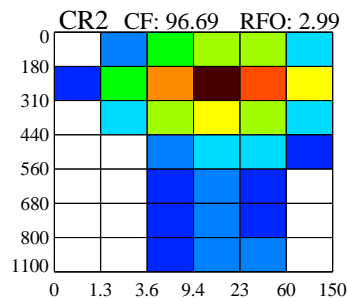
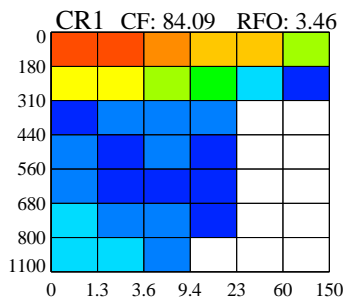


Our thinking

- 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”



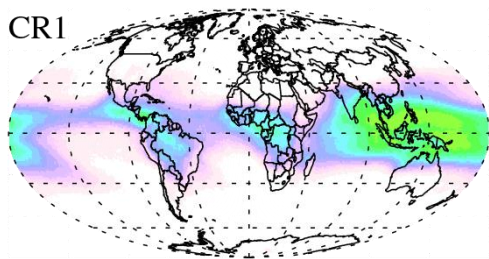
The 12 MODIS Collection 6 CRs



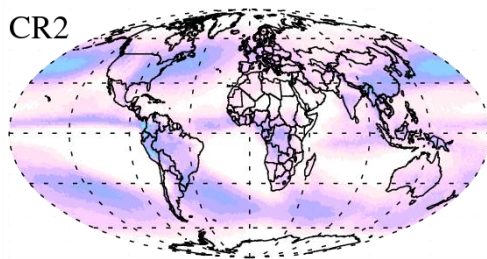


Where the CRs occur

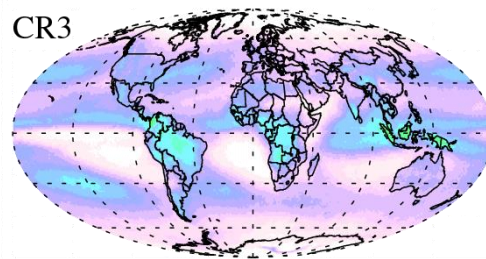
CR1



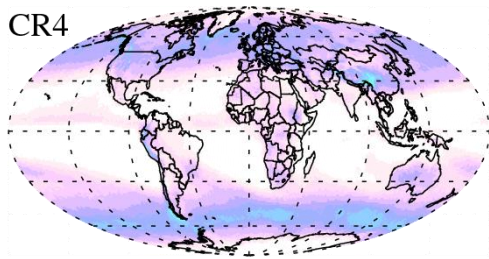
CR2



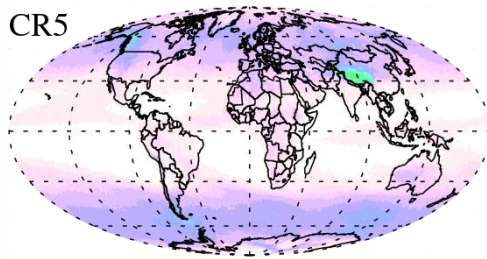
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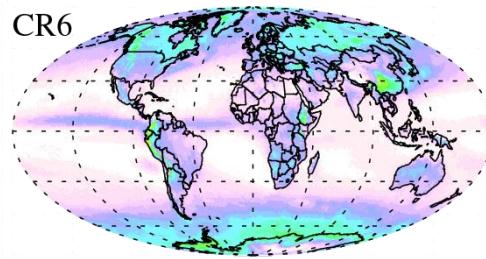
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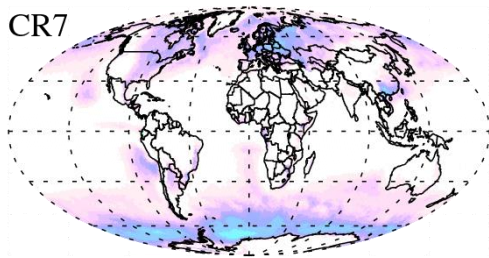
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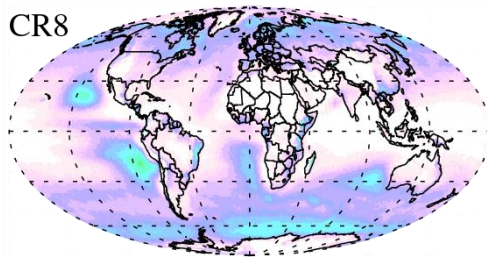
CR6



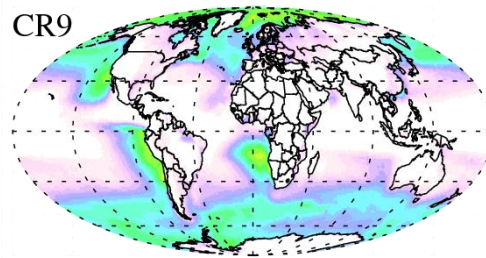
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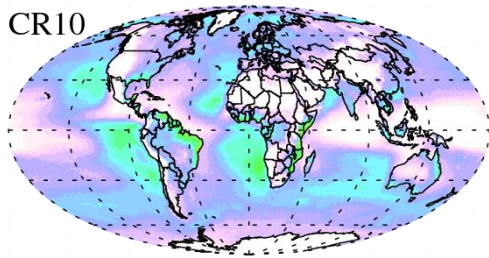
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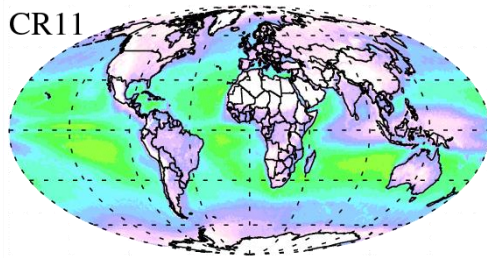
CR9



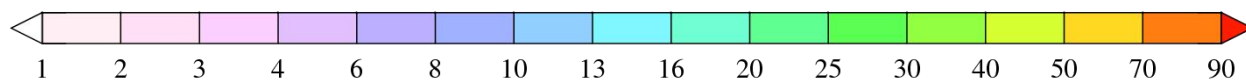
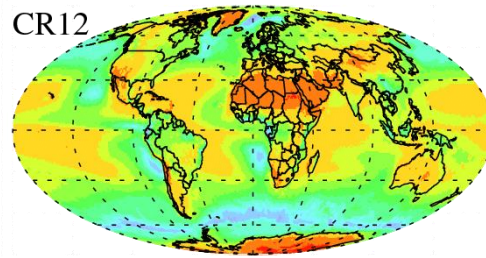
CR10



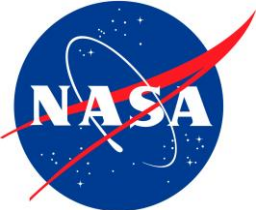
CR11



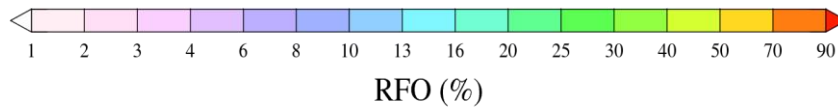
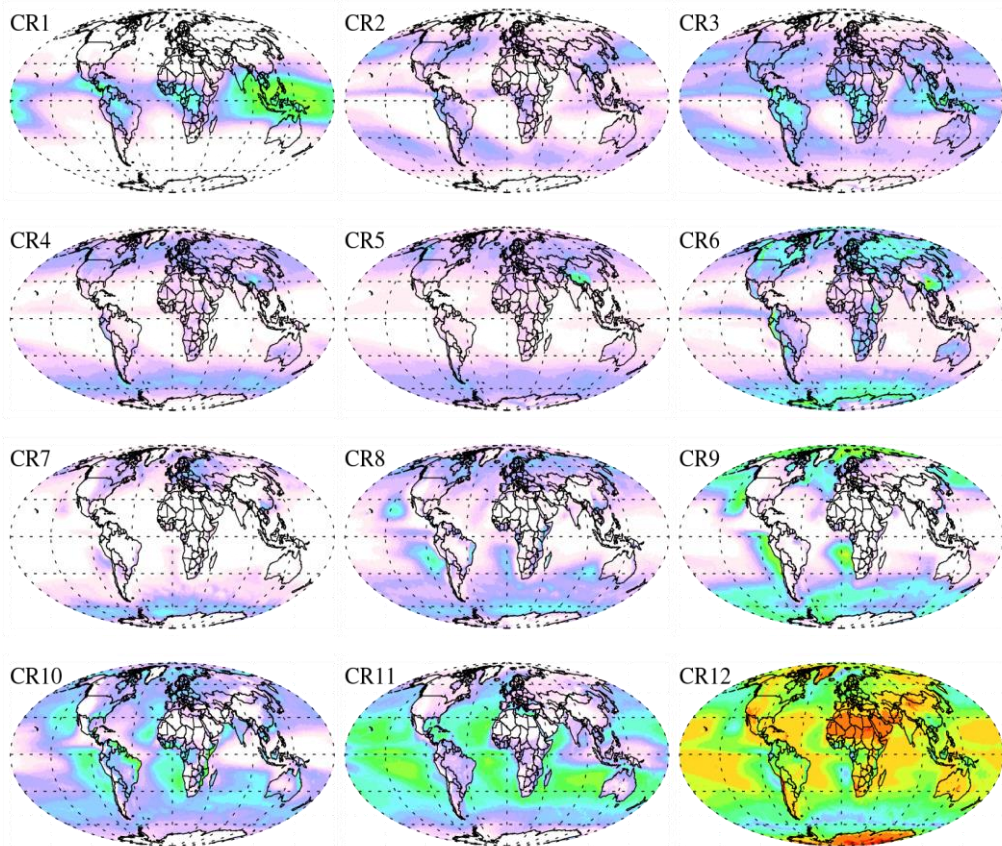
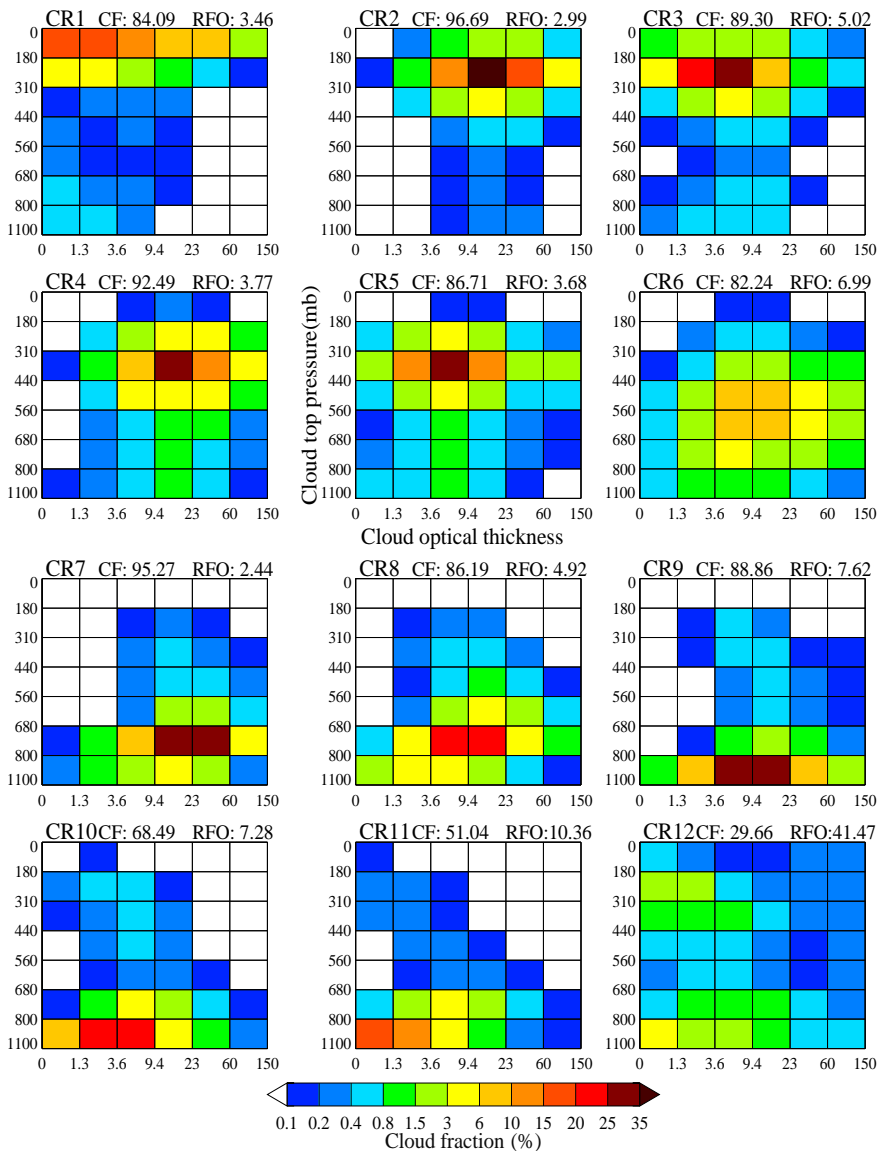
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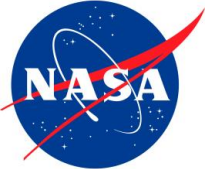


RFO (%)

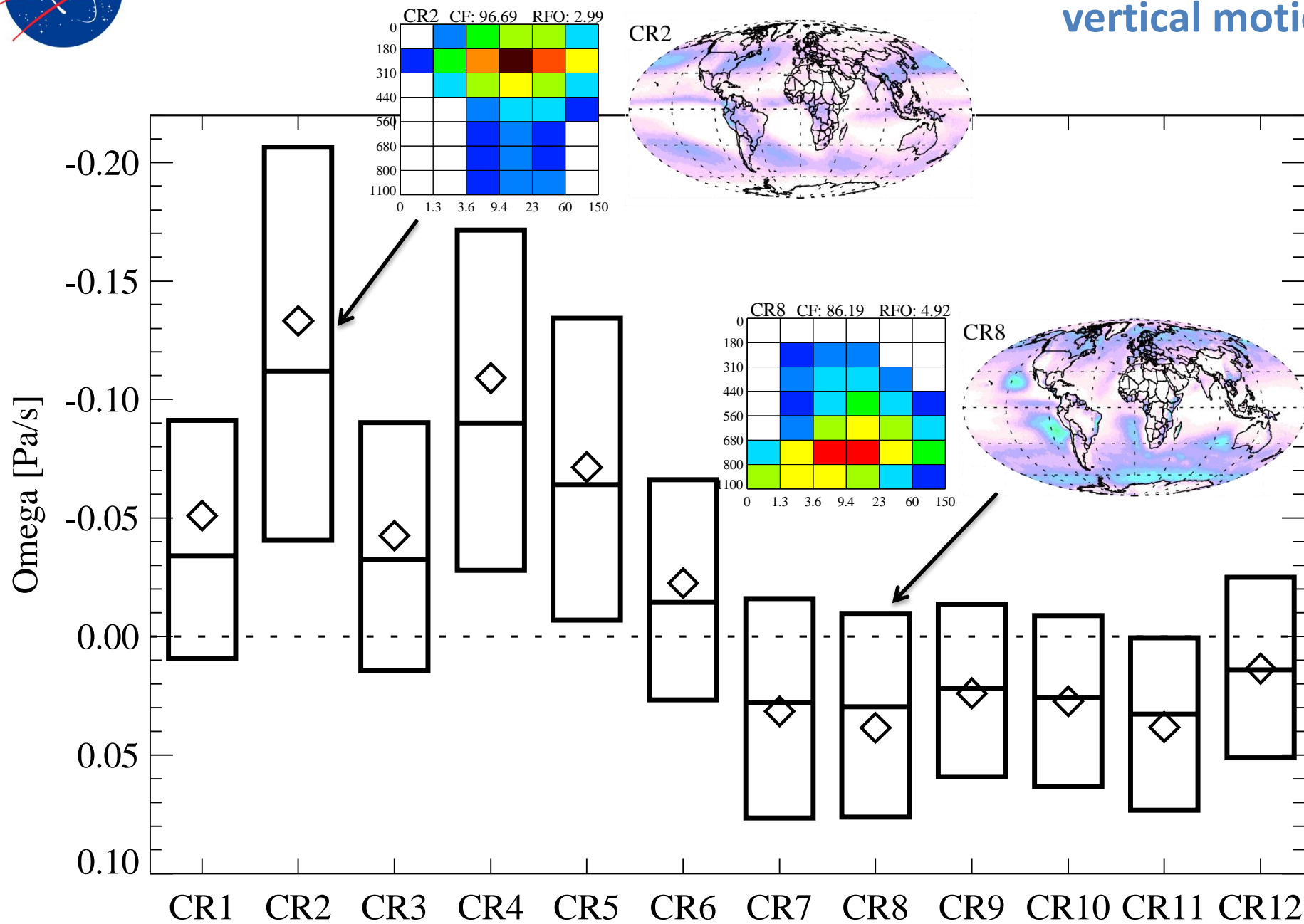


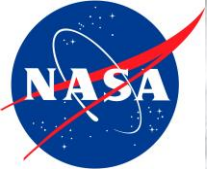
The full picture





CRs and large-scale vertical motion





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)



AOD Determination

1)

	Aqua CRX	

	Terra CRX	

	Aqua AOD	

	Terra AOD	

$$\text{AOD} = (\text{Aqua AOD} + \text{Terra AOD}) / 2.$$

2)

	Aqua CRX	

	Terra CRX	

	Aqua AOD	

	Nan	

	Aqua CRX	

	Terra CRX	

	Nan	

	Terra AOD	

$$\text{AOD} = \text{Aqua AOD} \quad \text{OR} \quad \text{AOD} = \text{Terra AOD}$$

3)

	Aqua CRX	

	Terra CRX	

	Aqua AOD _1	
	Nan	
Aqua AOD _2		

Terra AOD_1	Nan	

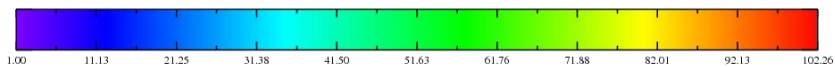
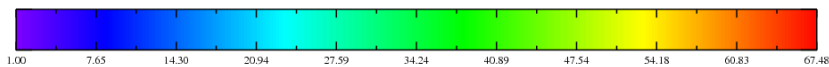
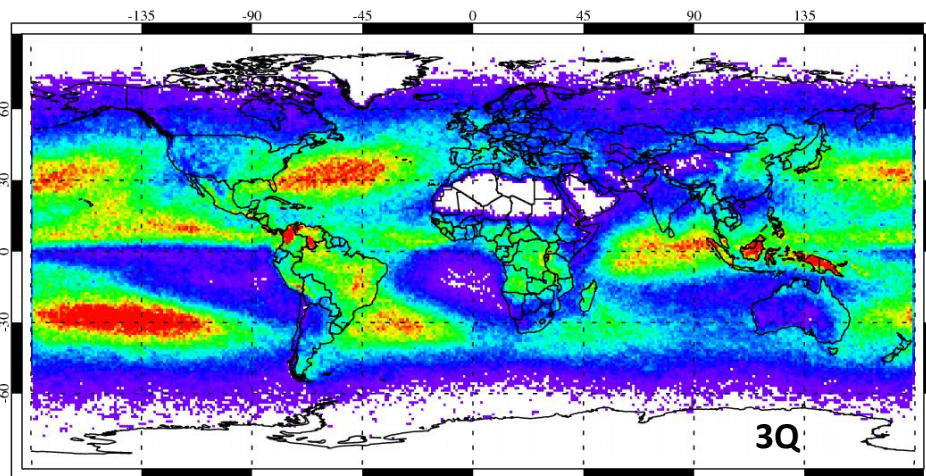
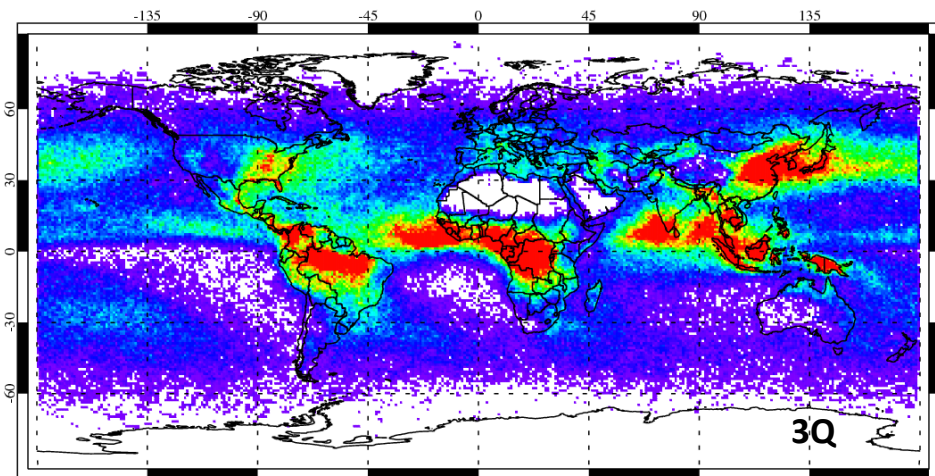
$$\text{AOD} = (\text{Aqua_AOD_1} + \text{Aqua_AOD_2} + \text{Terra_AOD_1}) / 3.$$



Comparison of two AOD sampling options (CR3)

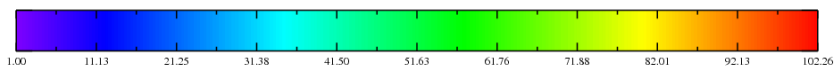
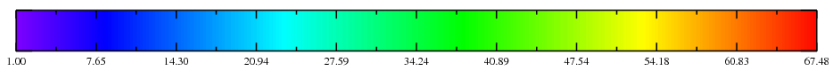
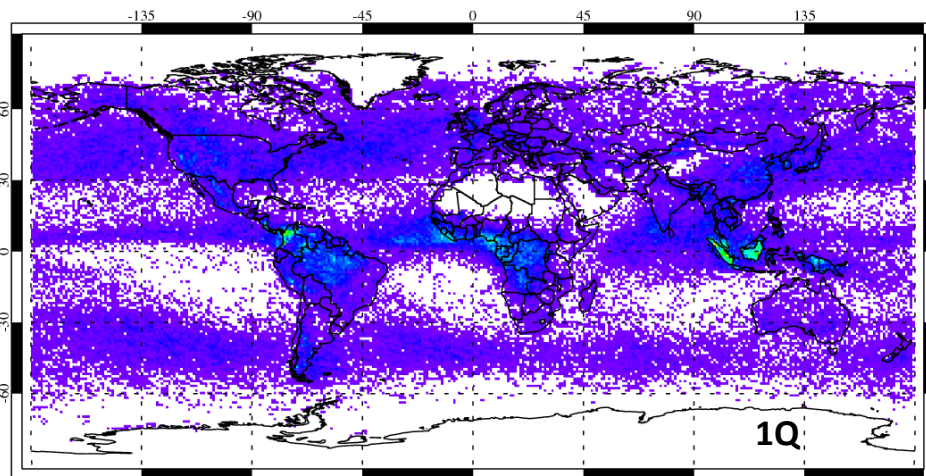
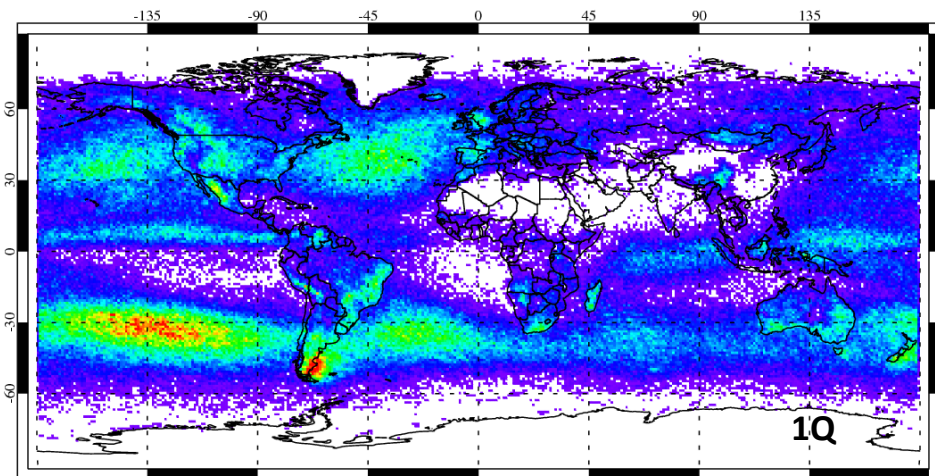
AOD distribution defined PER CR

AOD distribution defined PER GRIDCELL



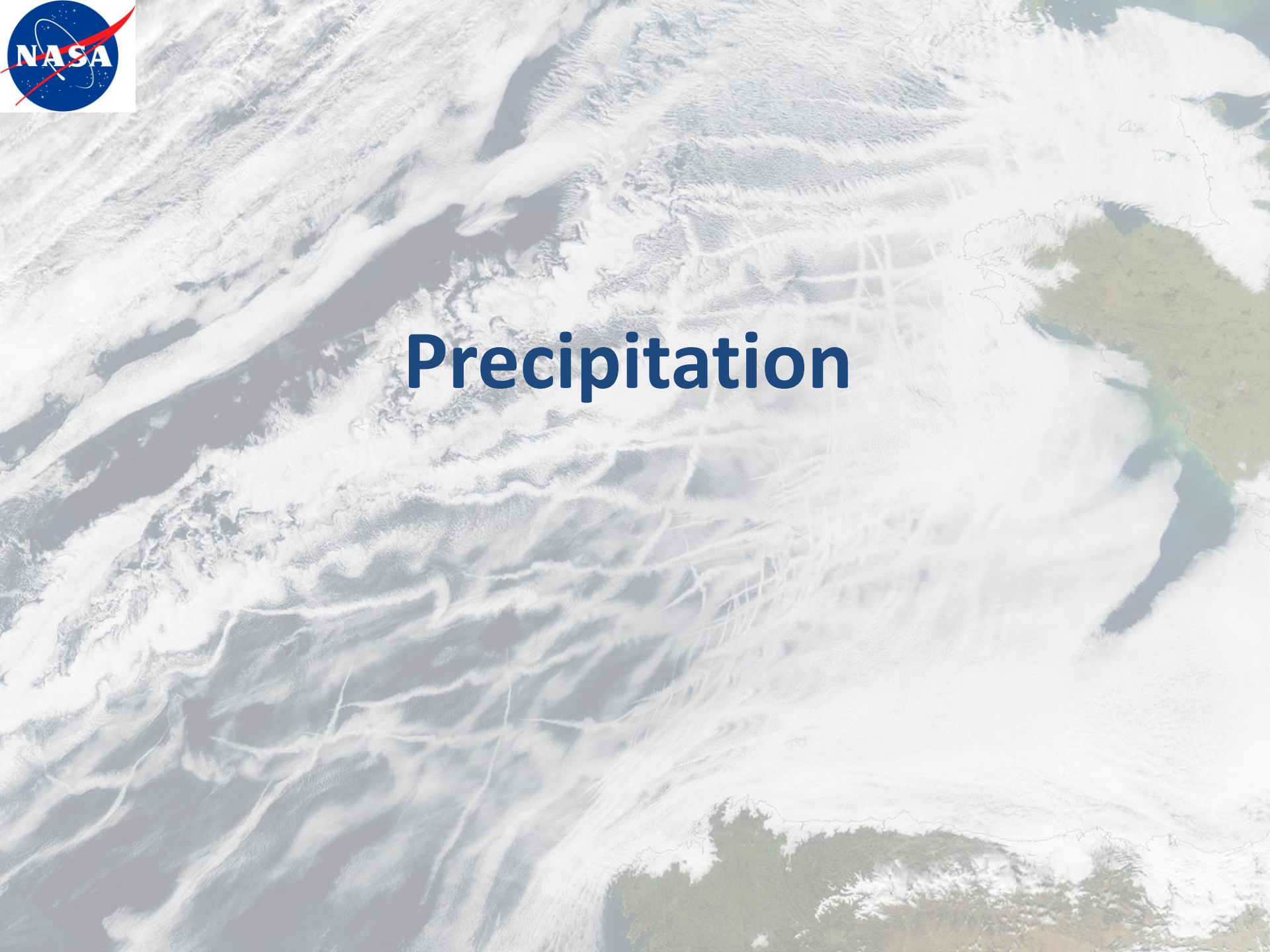
1Q AOD

1Q AOD





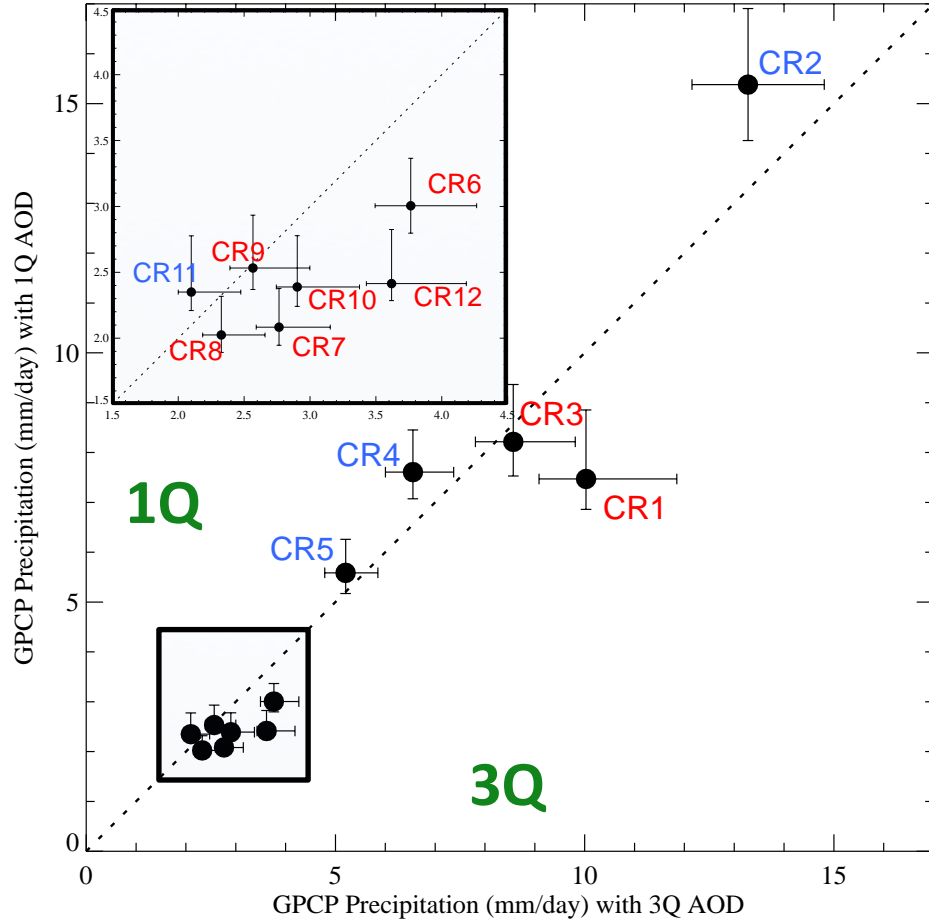
Precipitation



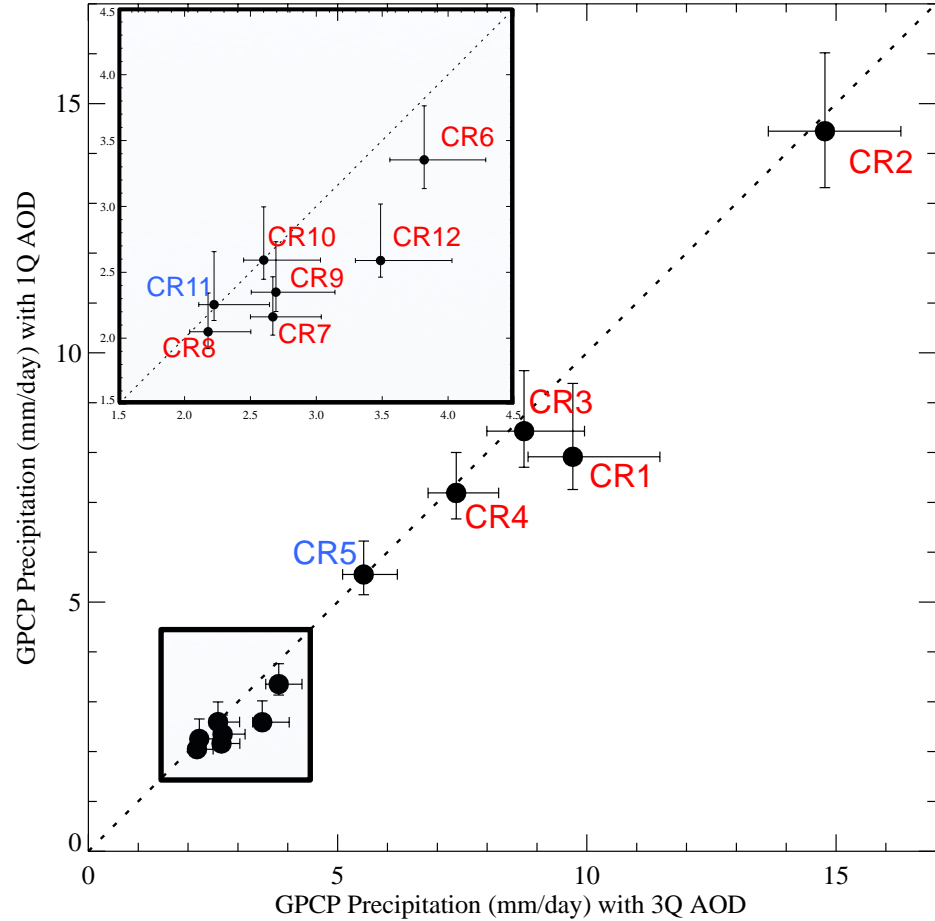


Precipitation comparison (RR>0) two sampling methods

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

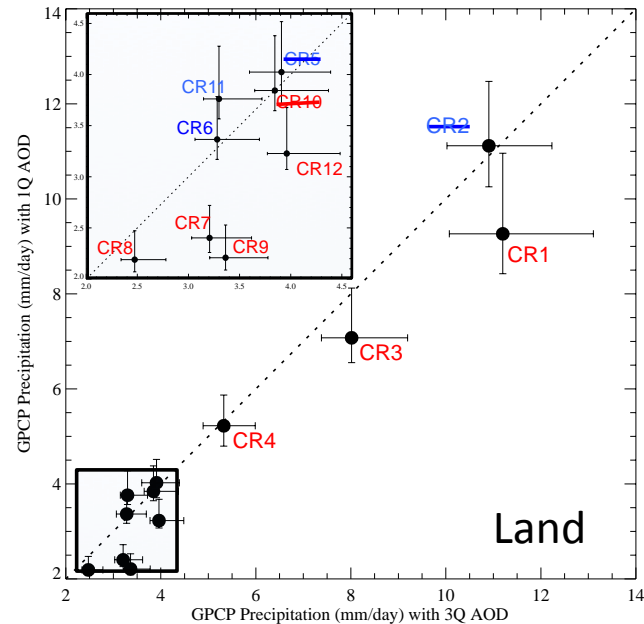
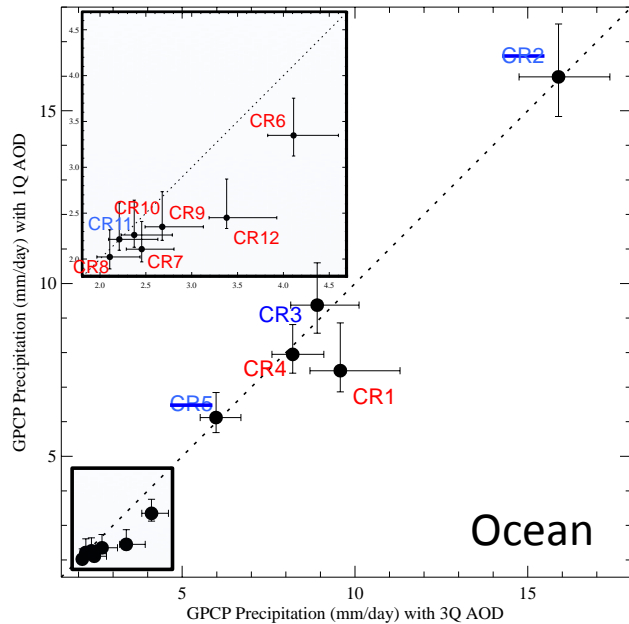
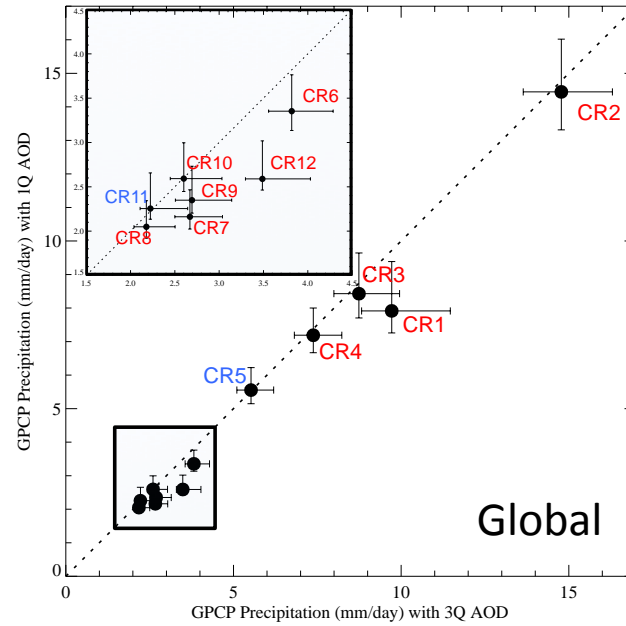


3Q/1Q AOD defined by per Grid per Season



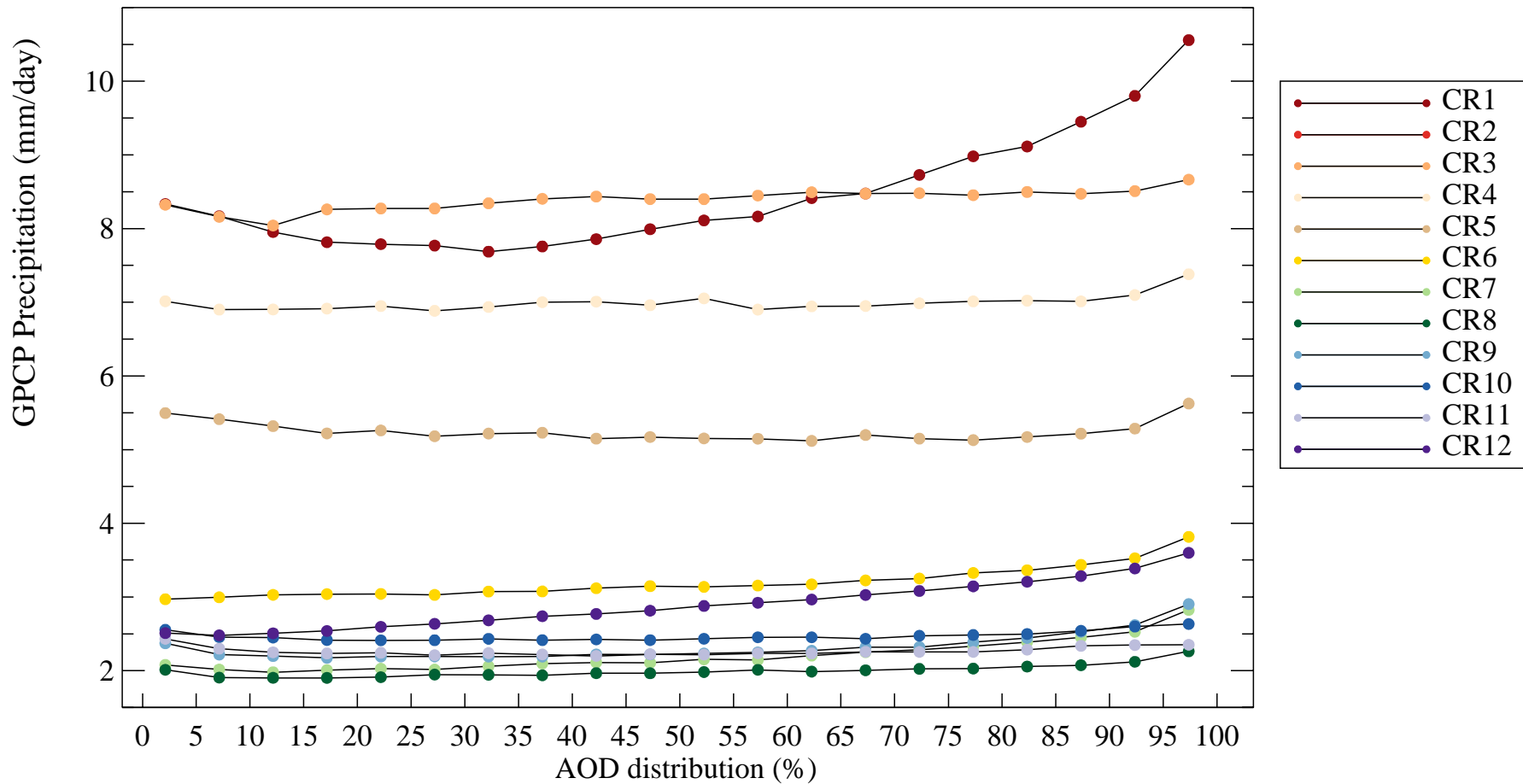
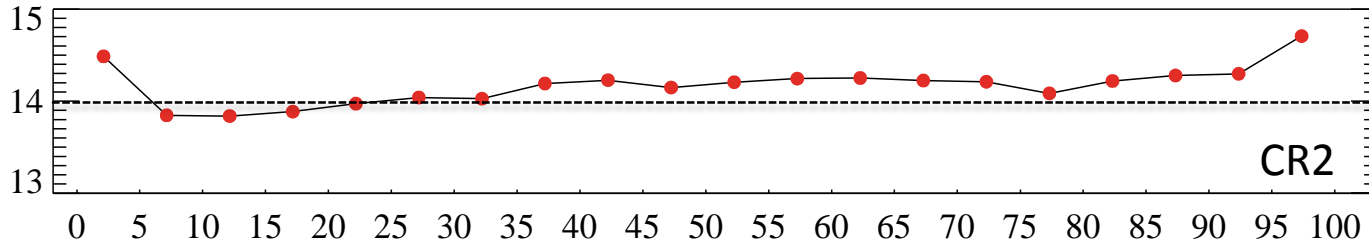


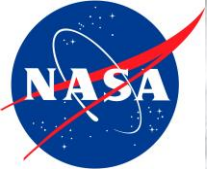
Precipitation (RR>0) comparison (Land-Ocean)



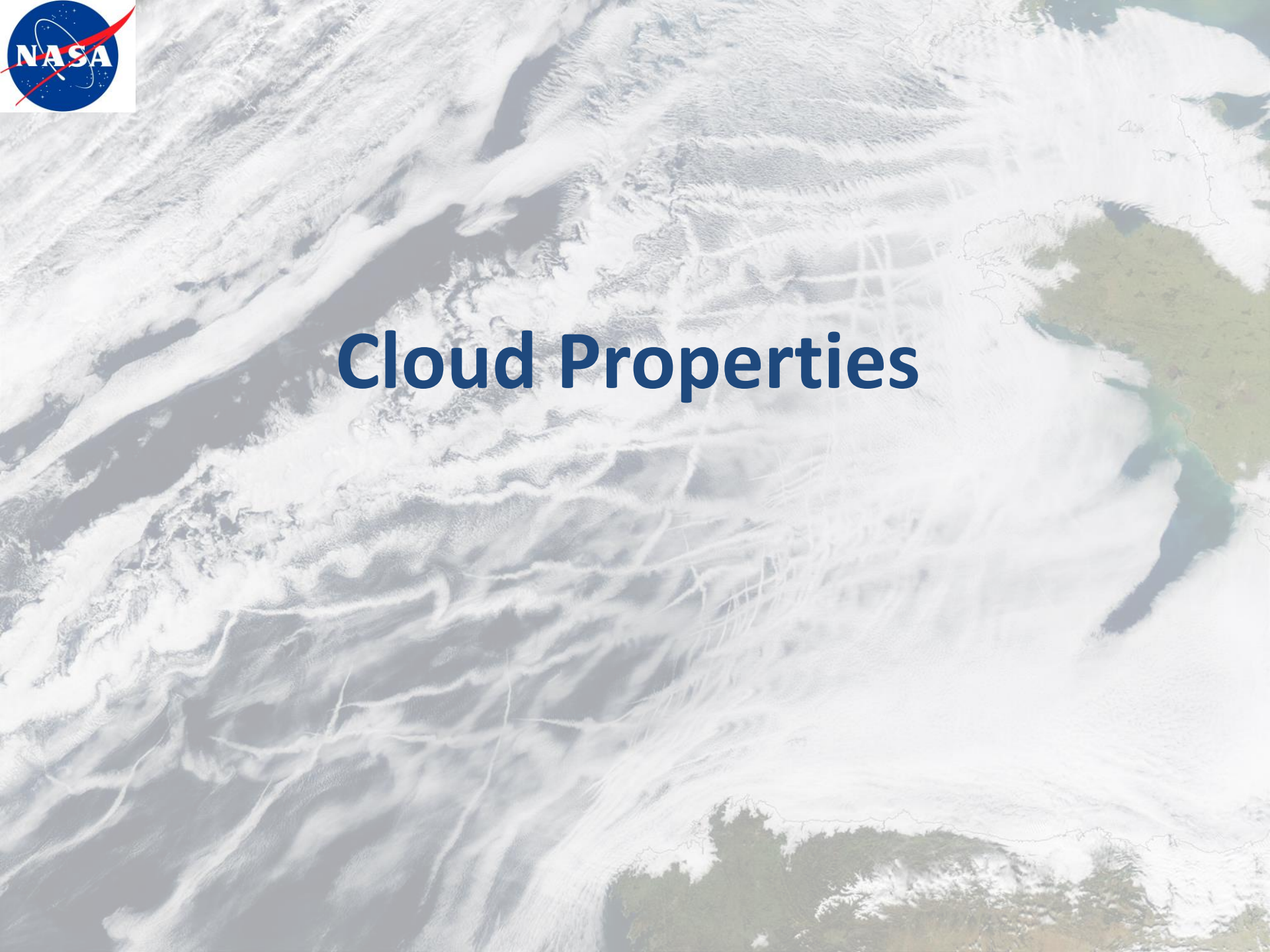


Precipitation (RR>0) vs AOD percentile





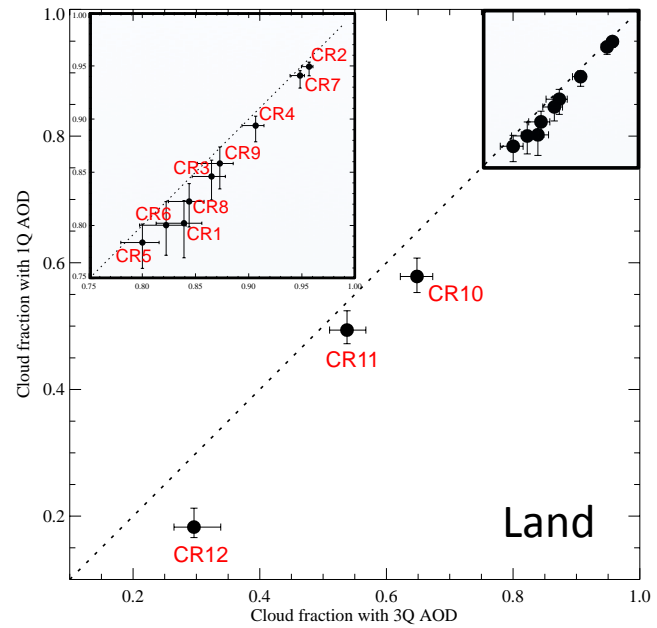
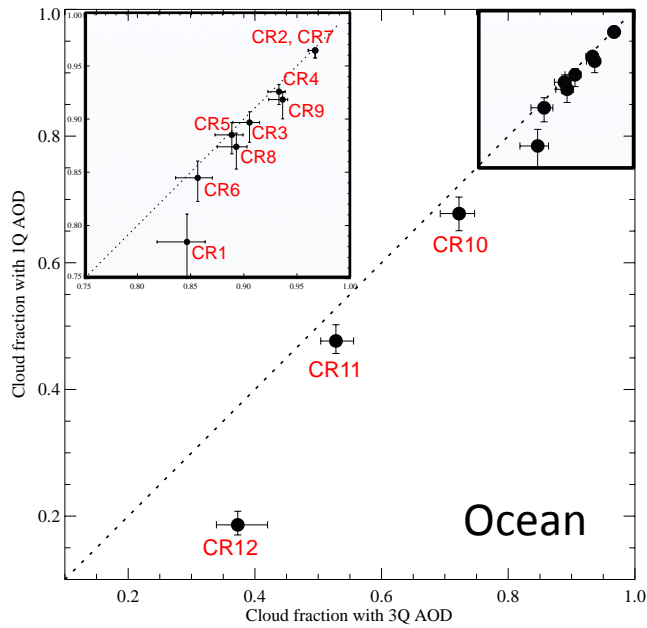
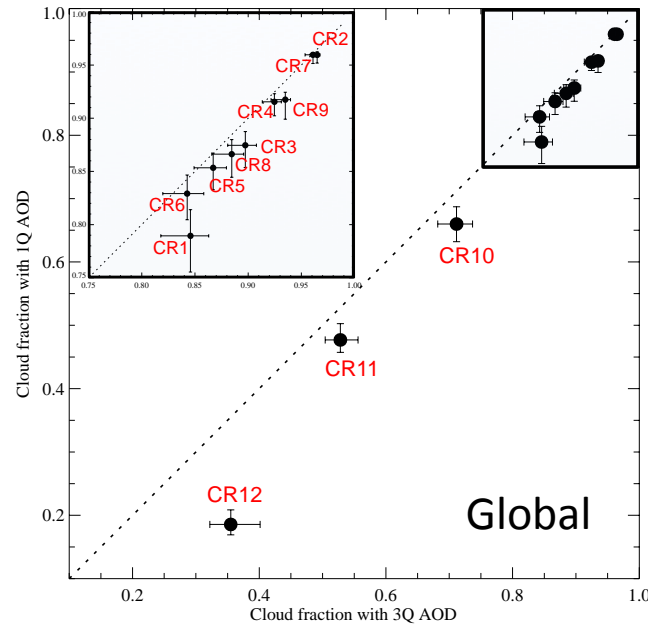
Cloud Properties





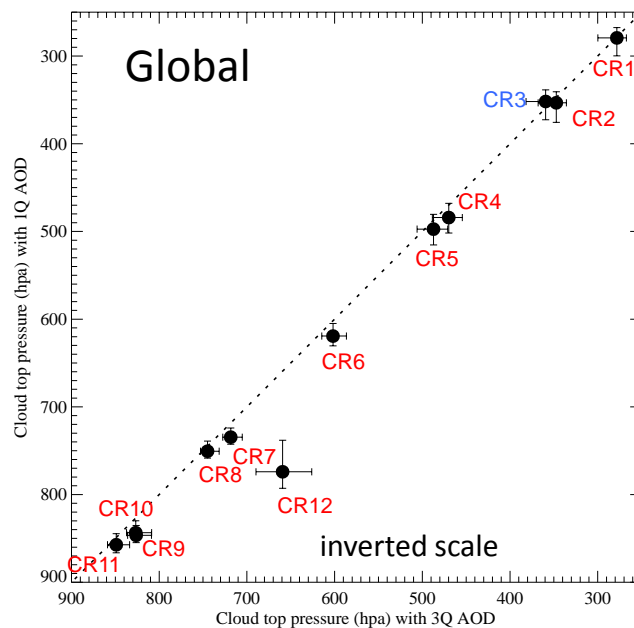
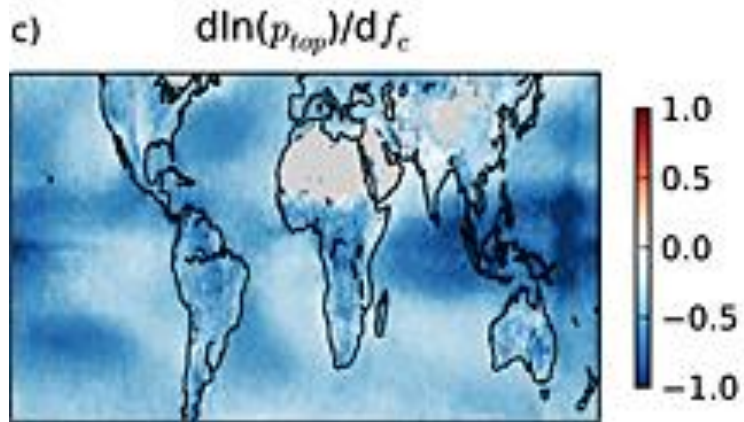
Cloud fraction

Red=meets expectations

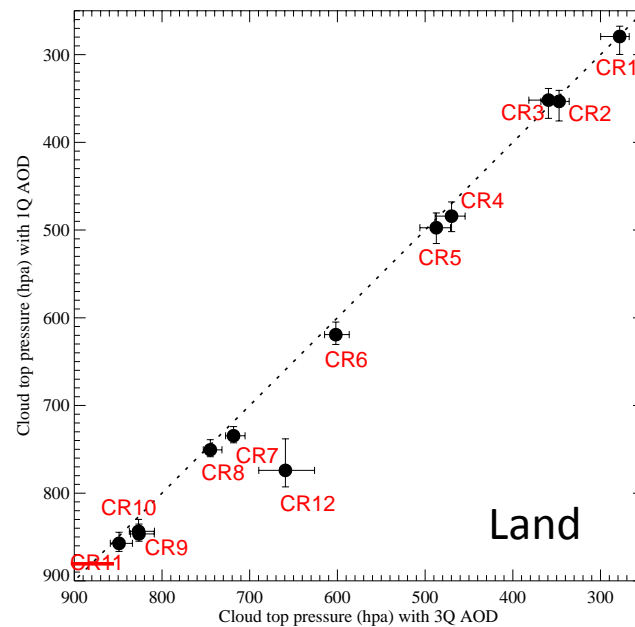
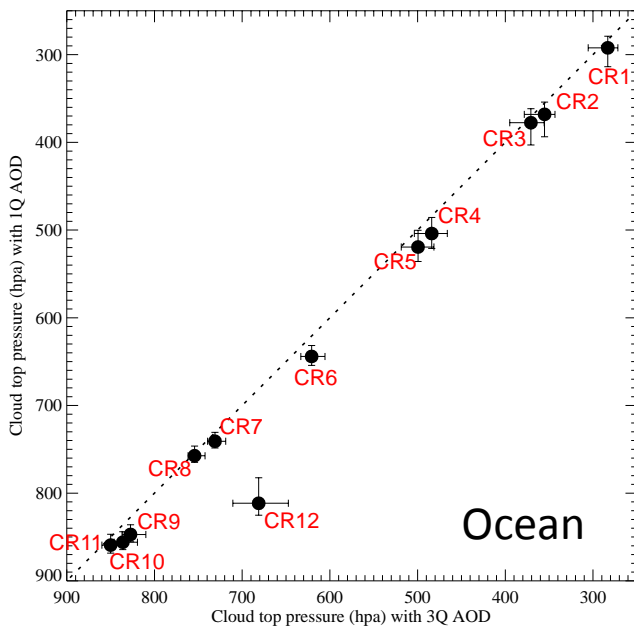




(Gryspeerdt et al. 2014)



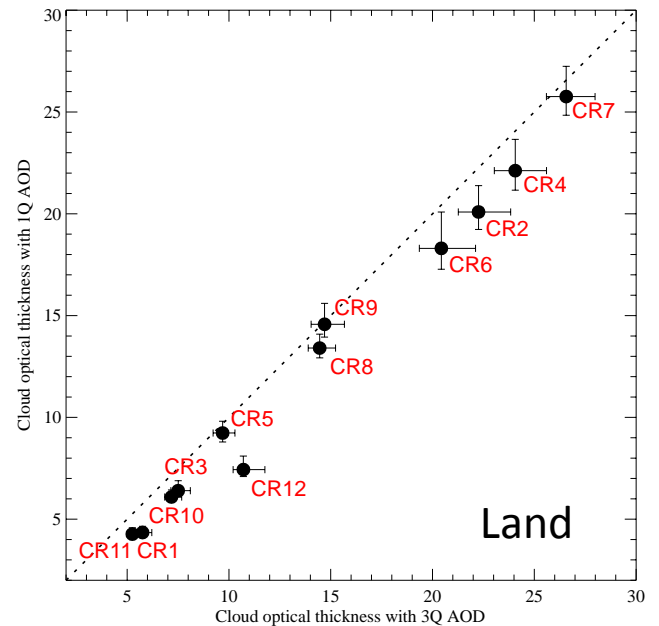
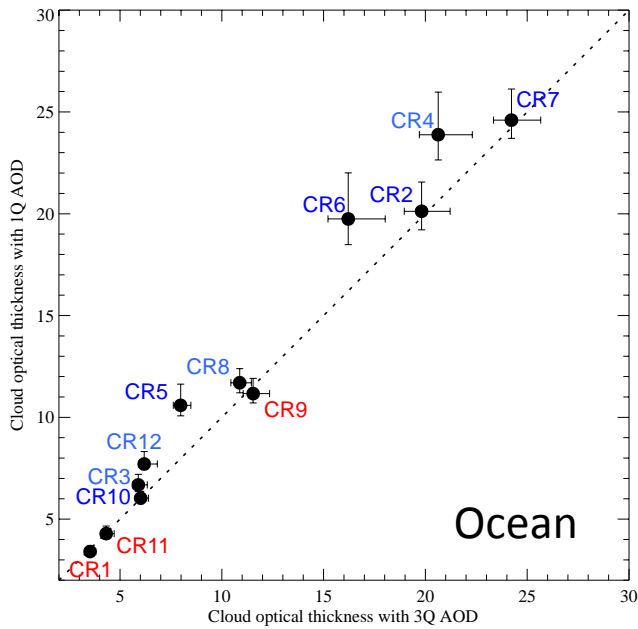
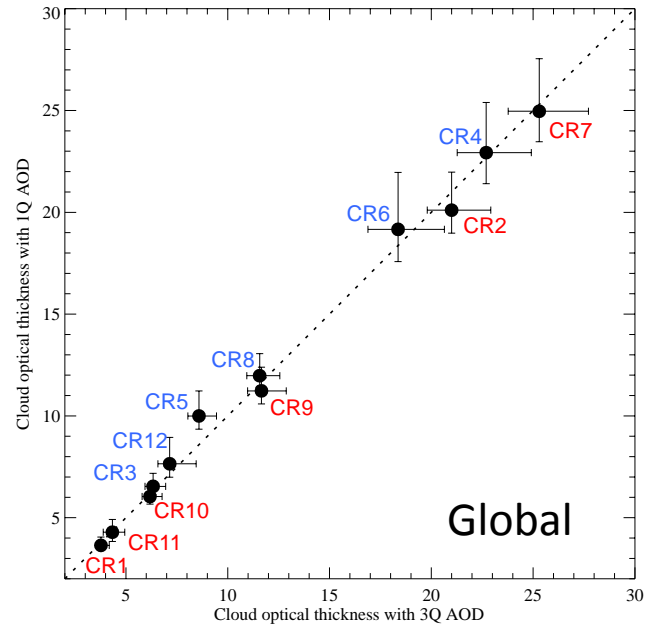
Cloud Top Pressure





Cloud optical thickness

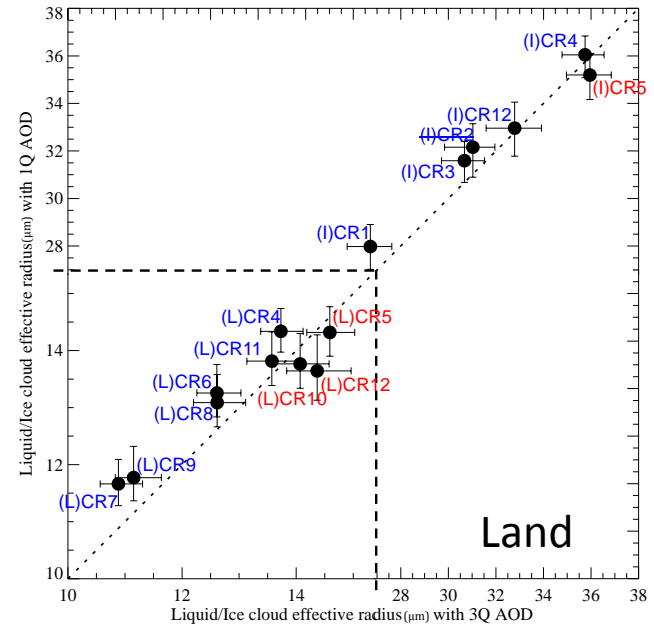
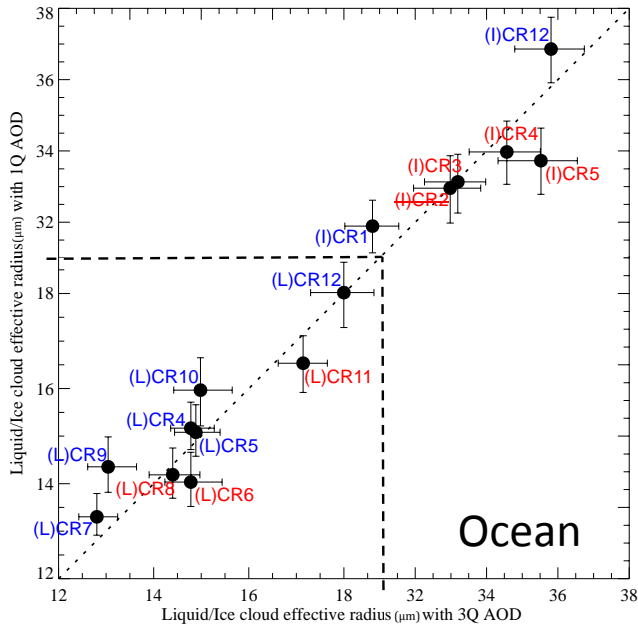
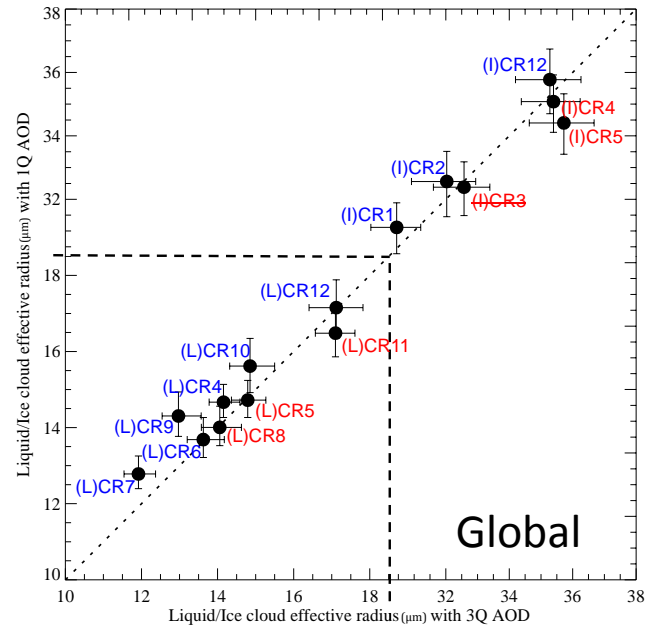
Red=meets expectations





Cloud effective radius

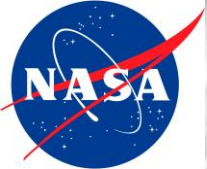
Blue=meets expectations





Summary and parting thoughts

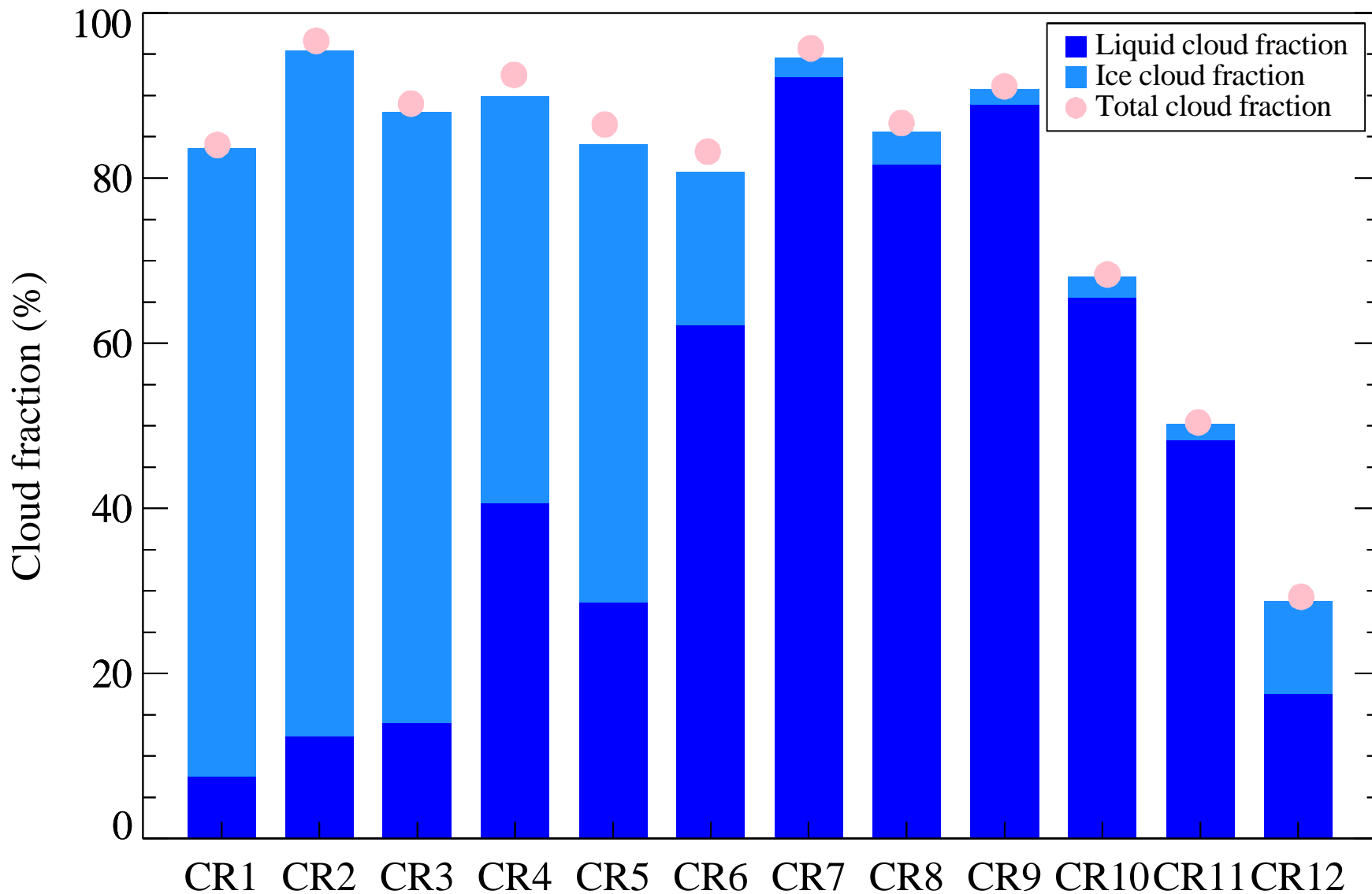
- We propose that Aerosol-Cloud-Precipitation relationships be examined on a “cloud regime” basis
 - This helps us examine aerosol influence under more “similar” conditions
- Even then, the outcomes depend on how one samples AOD distributions (weaker or stronger constraints on meteorology)
- Most times, 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)



Additional Slides

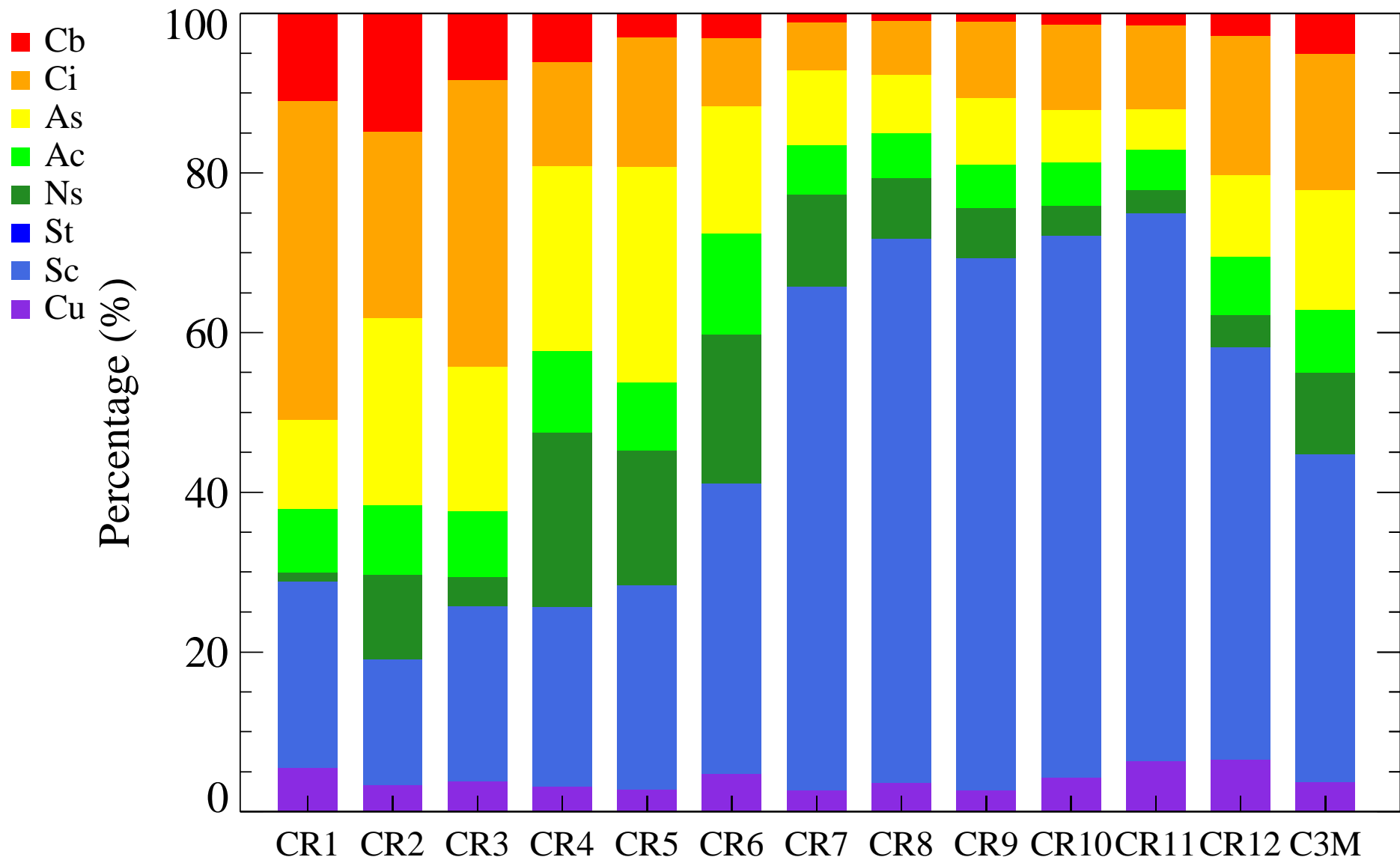


CR thermodynamic phase



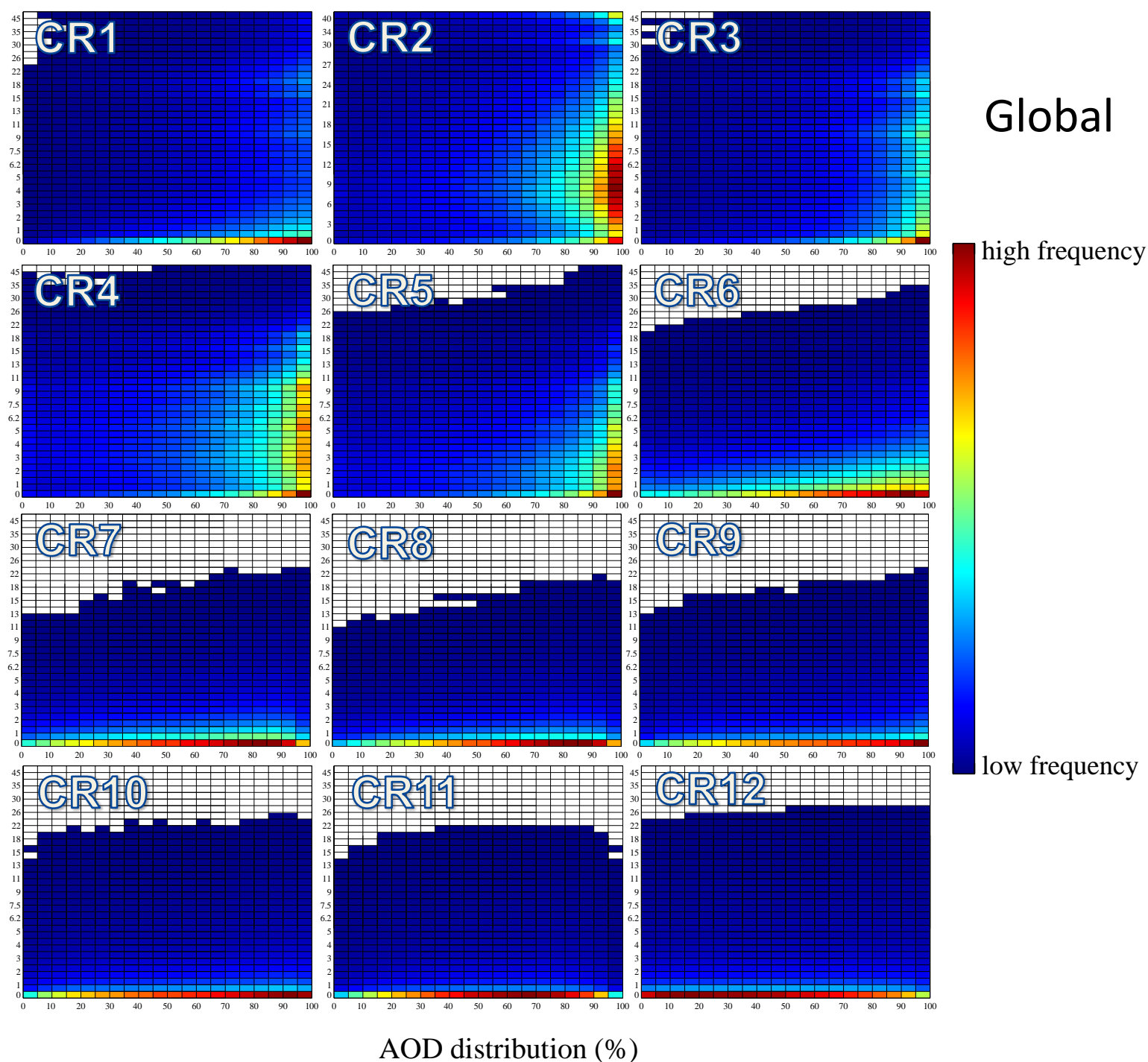


CR cloud type breakdown per CloudSat





GPCP Precipitation(mm/day)



Global

high frequency

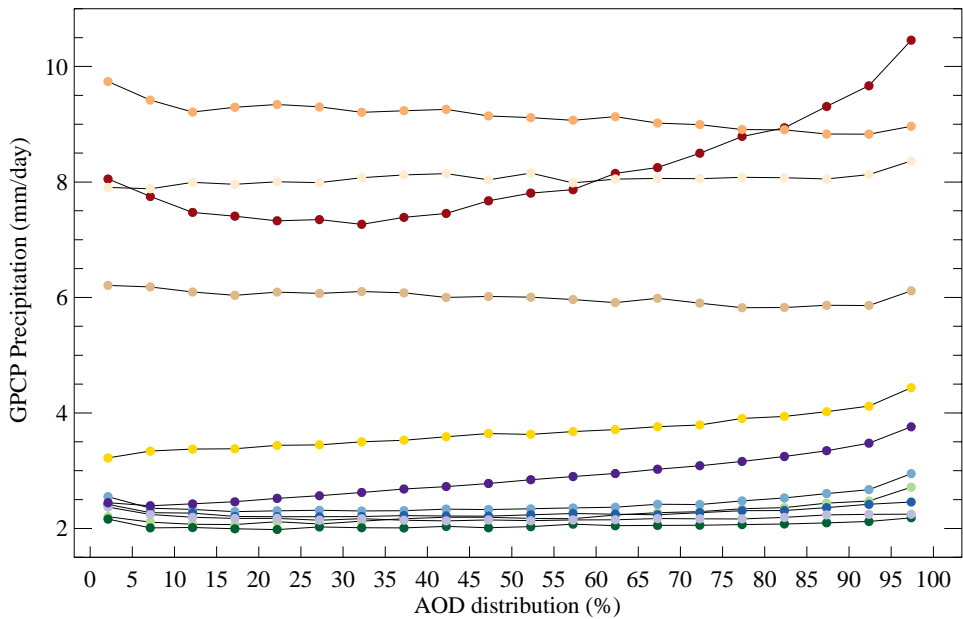
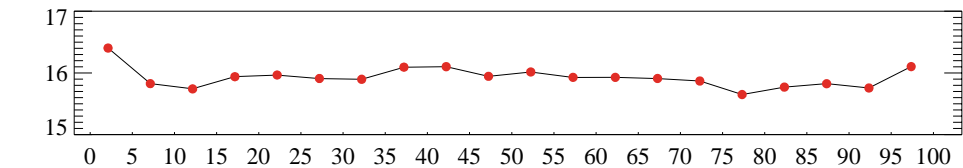
low frequency

AOD distribution (%)

Note that the Y-axis scale is not linear and different for CR2.

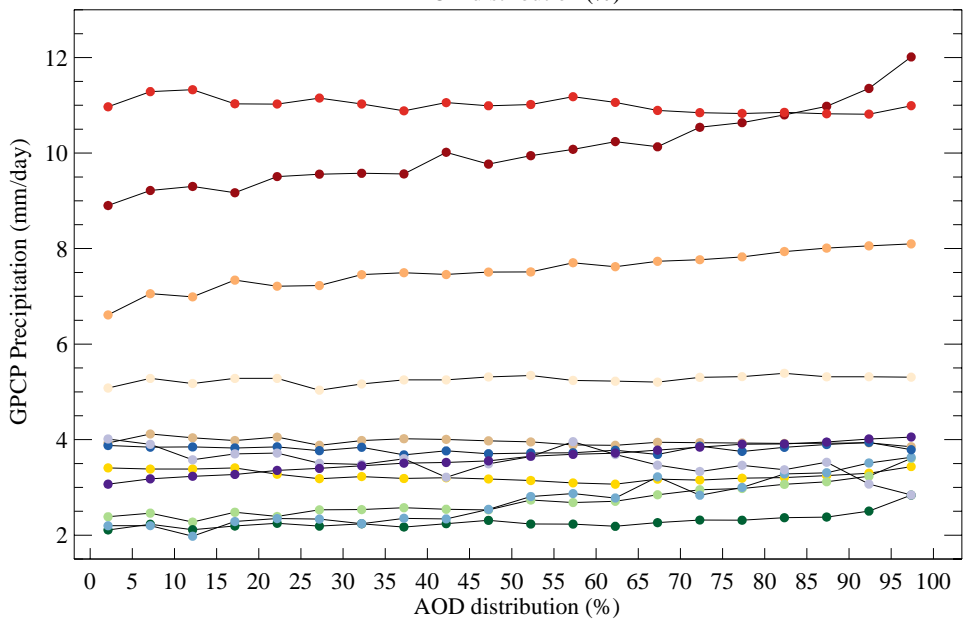


Ocean

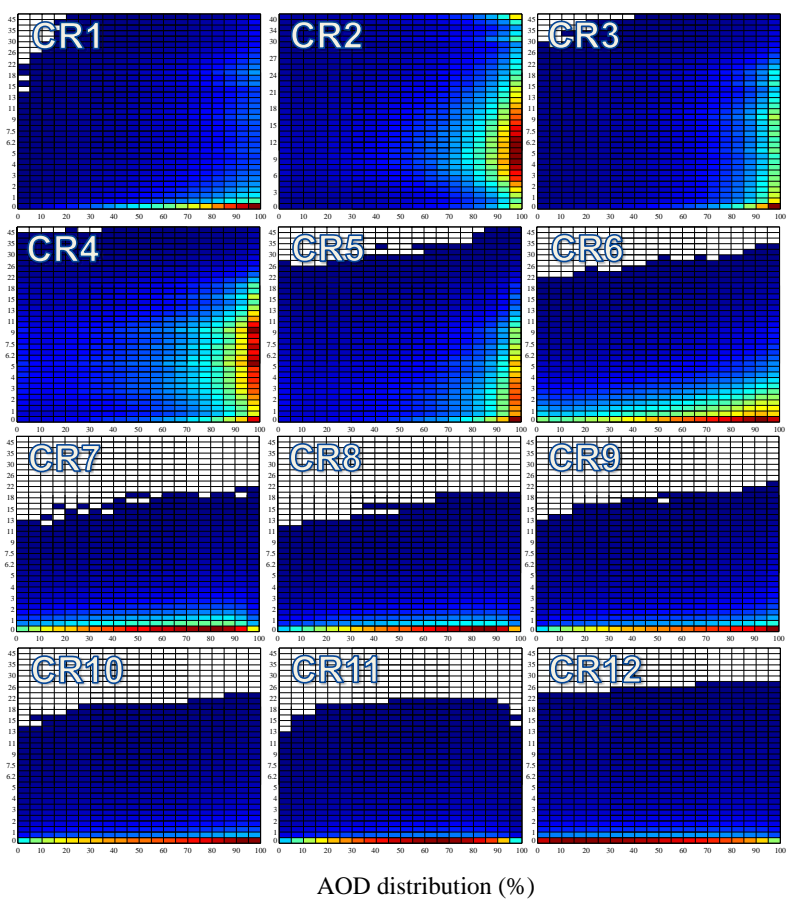


- CR1
- CR2
- CR3
- CR4
- CR5
- CR6
- CR7
- CR8
- CR9
- CR10
- CR11
- CR12

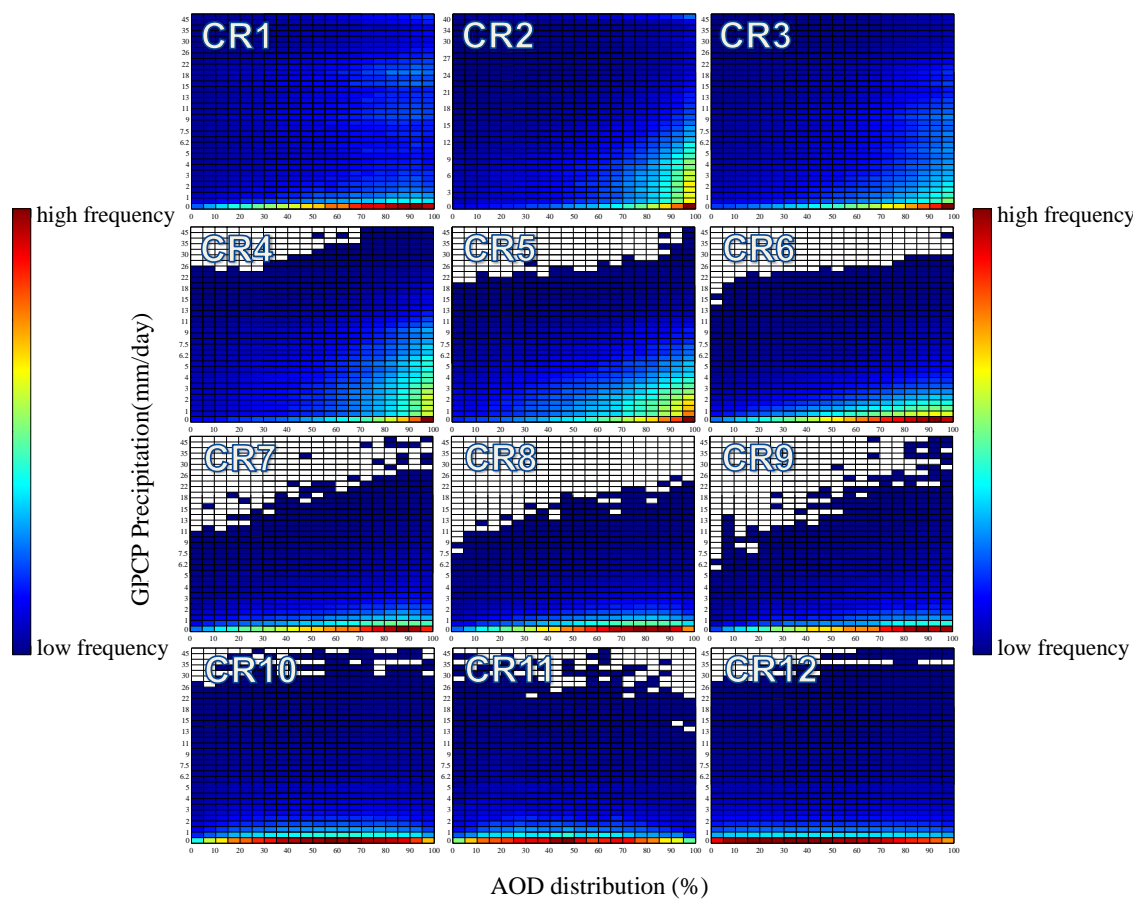
Land



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



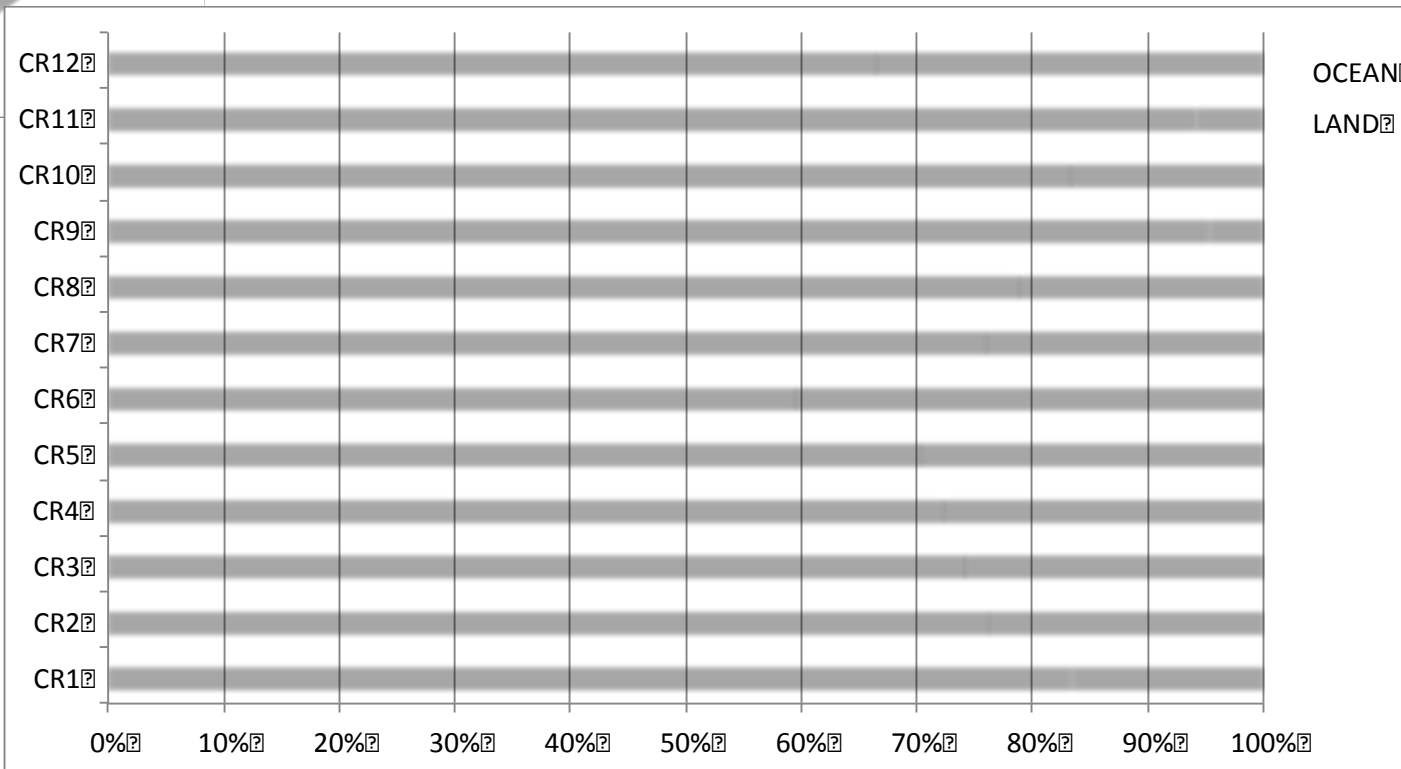
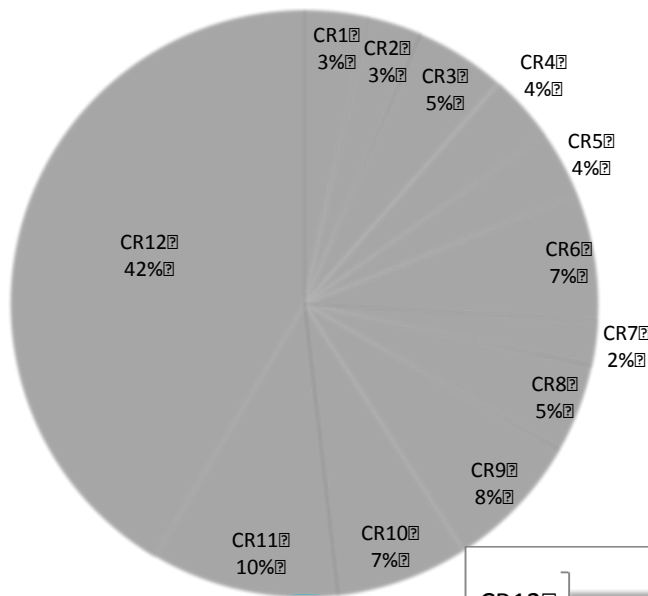
Ocean



Land

Note that the Y-axis scale is not linear and different for CR2.

MODIS Cloud Regime RFO (%)

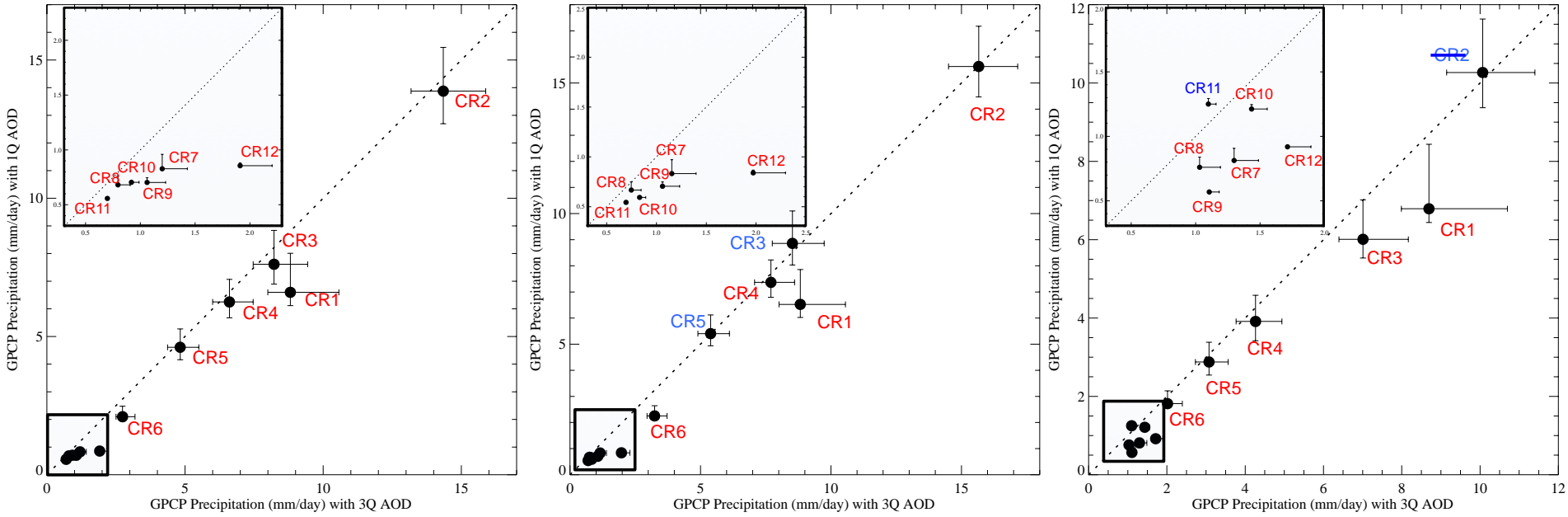


GPCP daily mean Precipitation ($P \geq 0$)

Global

Ocean

Land

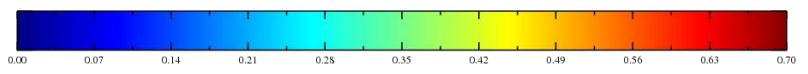
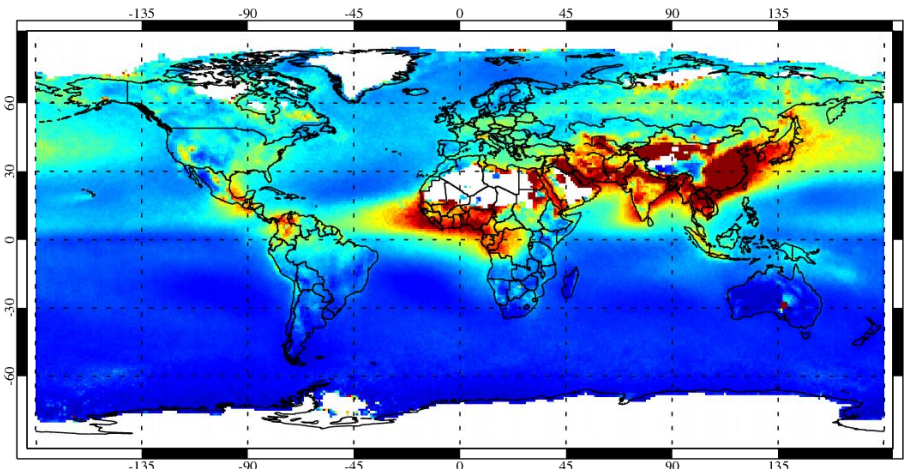


Scatter plot comparing Latitudinally-weighted mean precipitation rate (*including zero* precipitation) for upper 3q AOD and lower 1q AOD. The horizontal and vertical error bars indicate one fifth of the interquartile range of the distributions used to calculate the composite means; distance **from median 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)**.

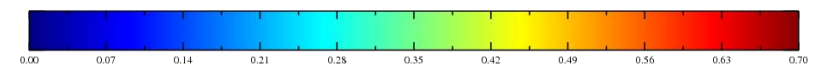
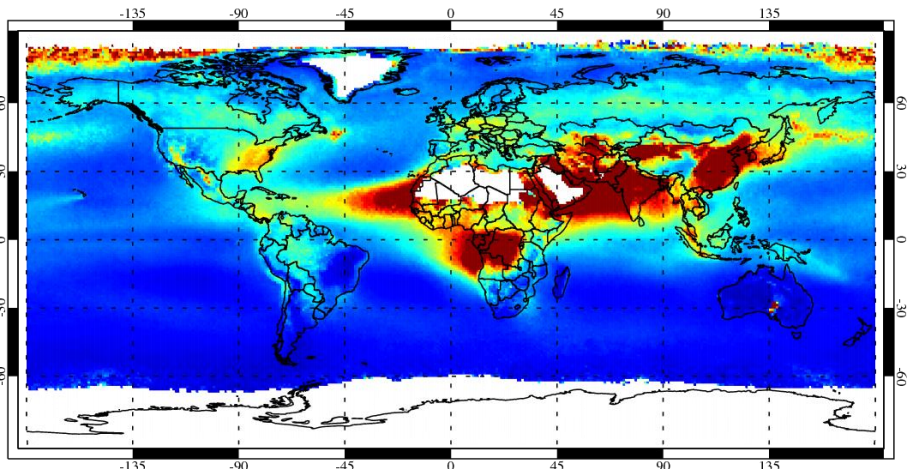
(MYD CR = MOD CR) + daily grid new AOD + daily mean GPCP

Assigned 3Q AOD

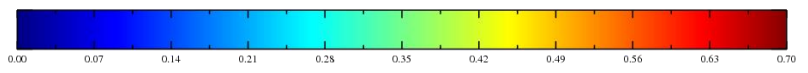
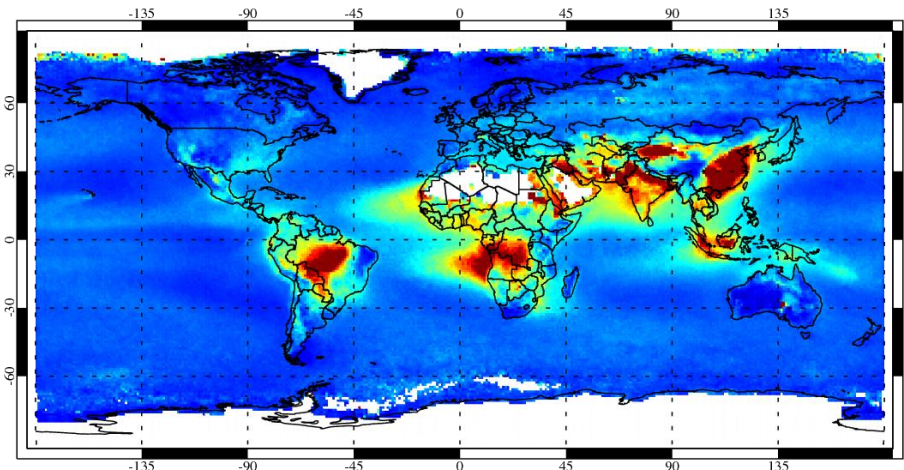
MAM



JJA

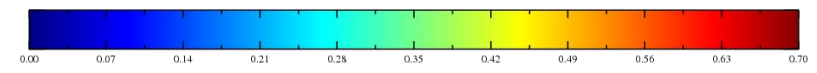
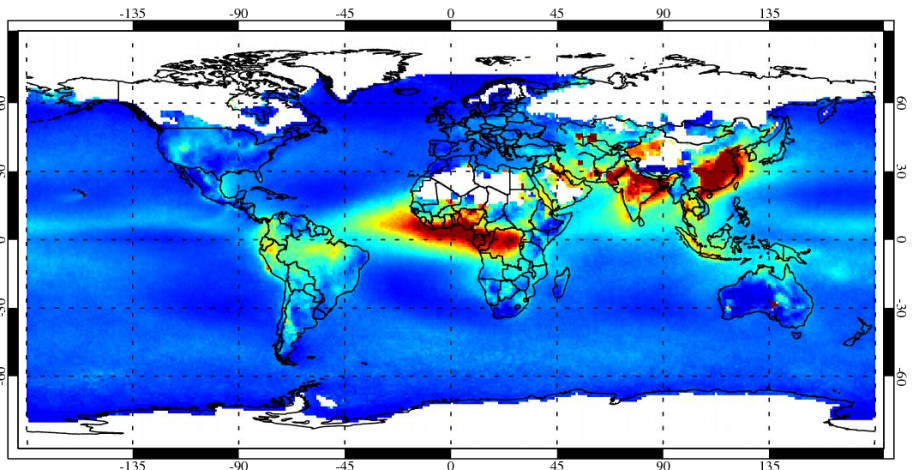


SON



AOD

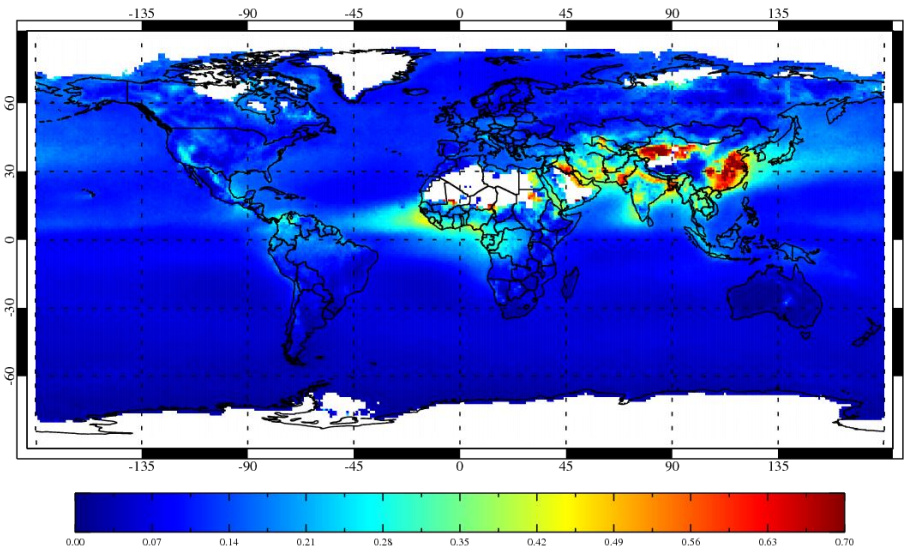
DJF



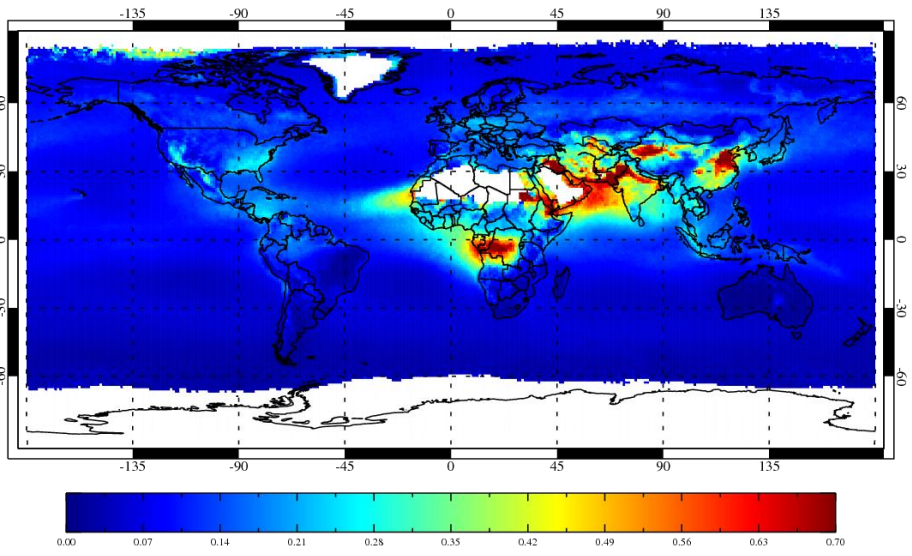
AOD

Assigned 1Q AOD

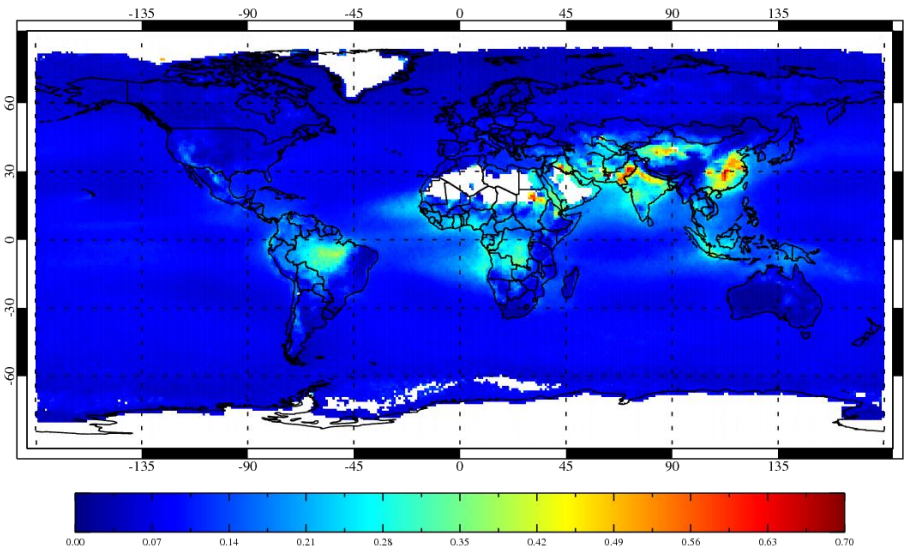
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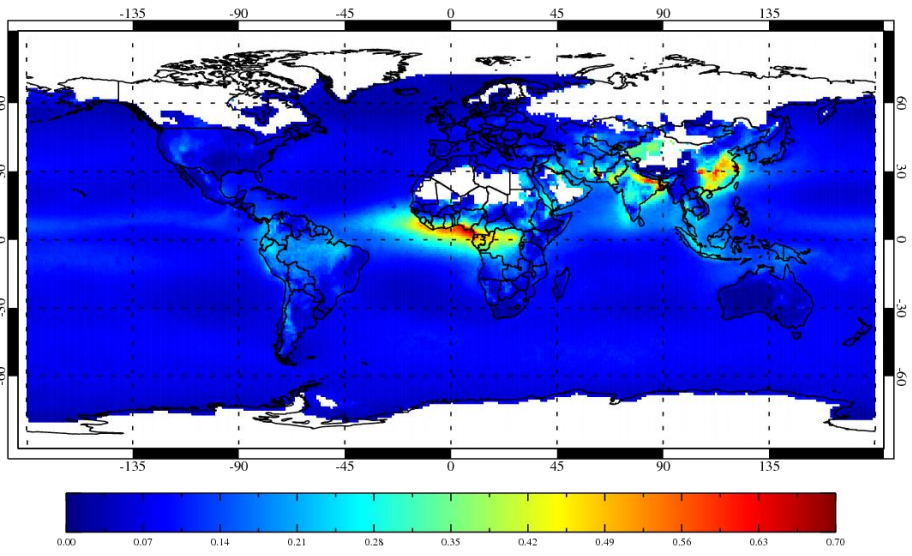
JJA



SON

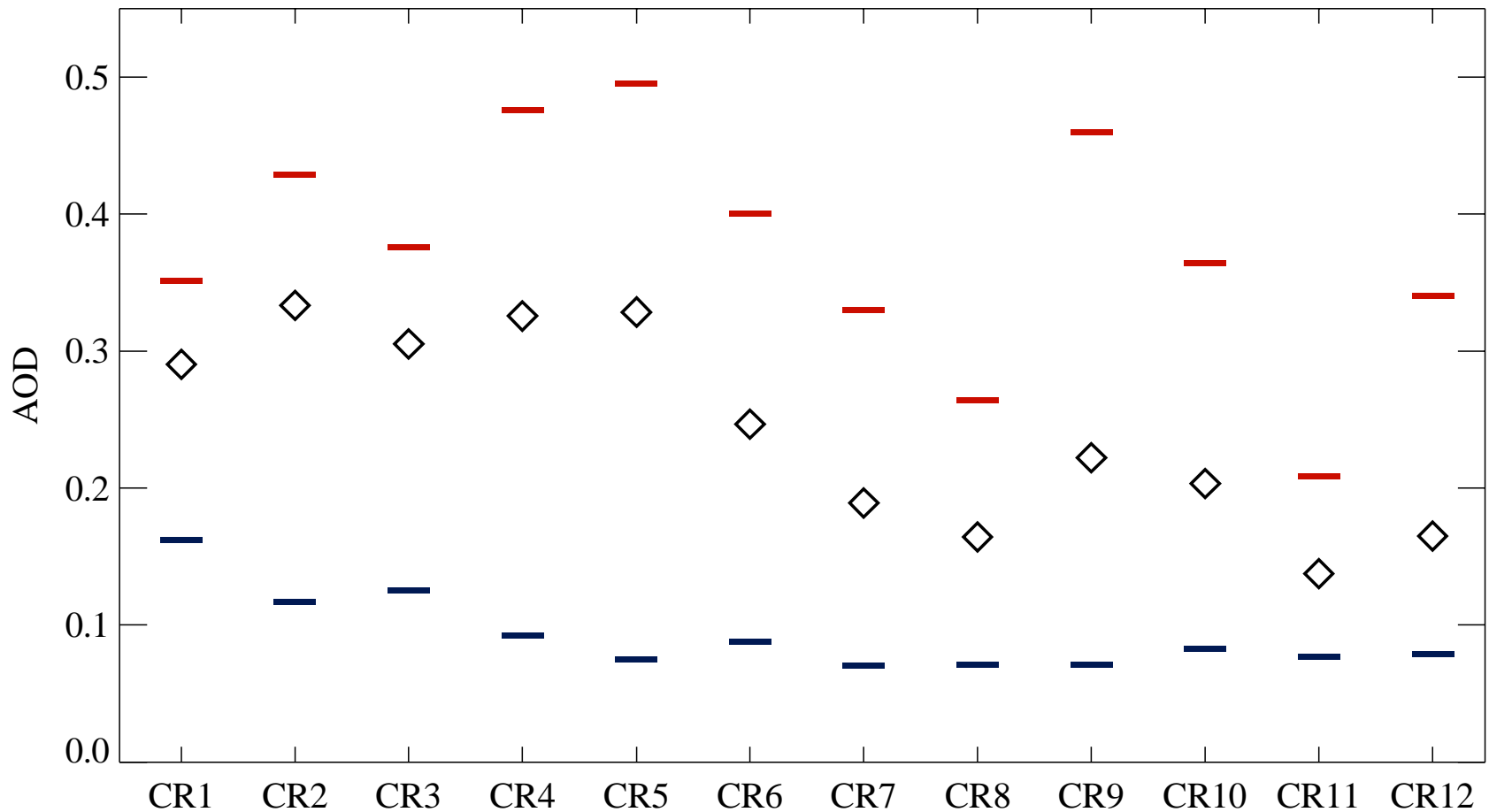


DJF



AOD

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.