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

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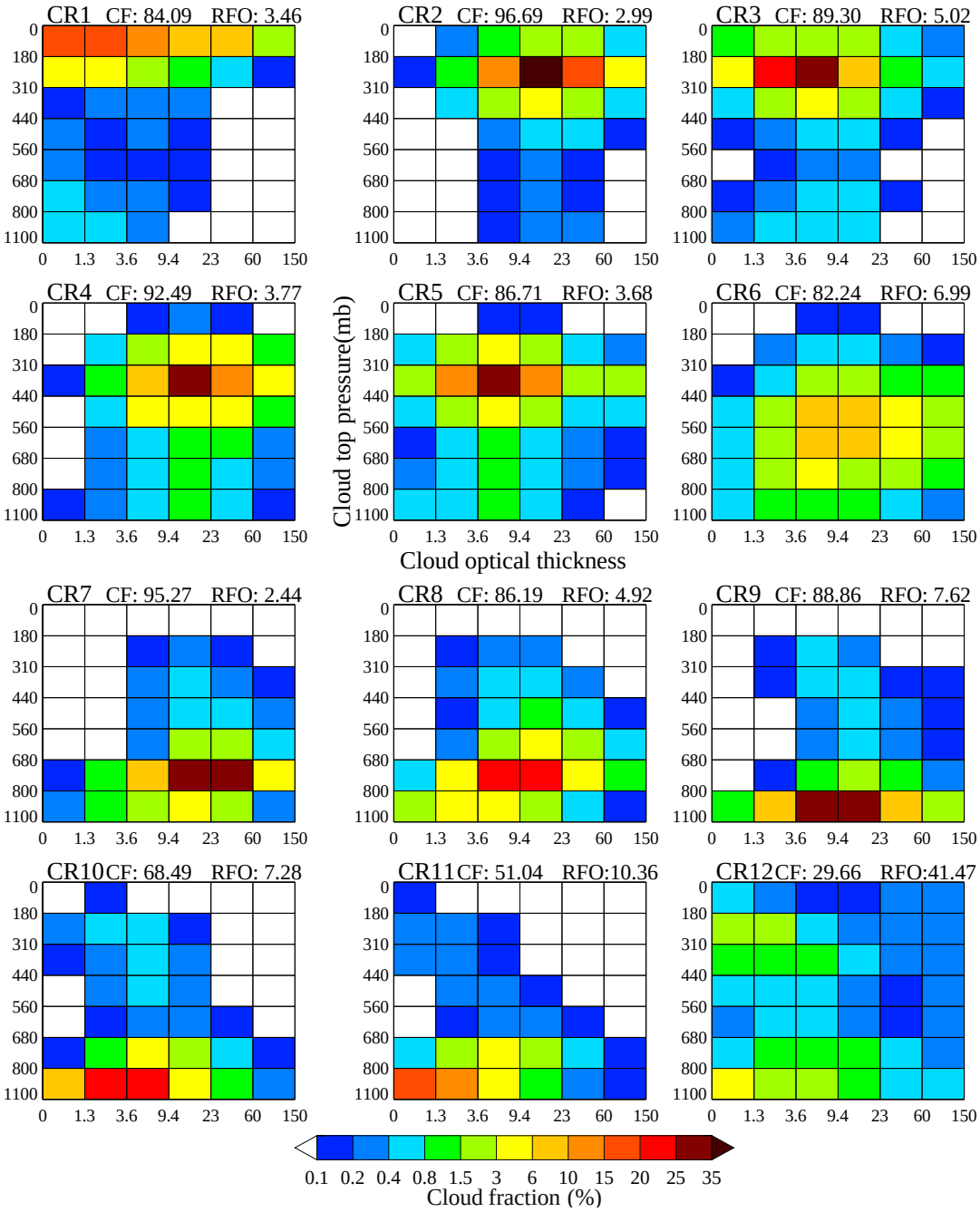
Acknowledgements: NASA's "The Science of Aqua and Terra" and "Modeling Analysis and Prediction (MAP)" programs

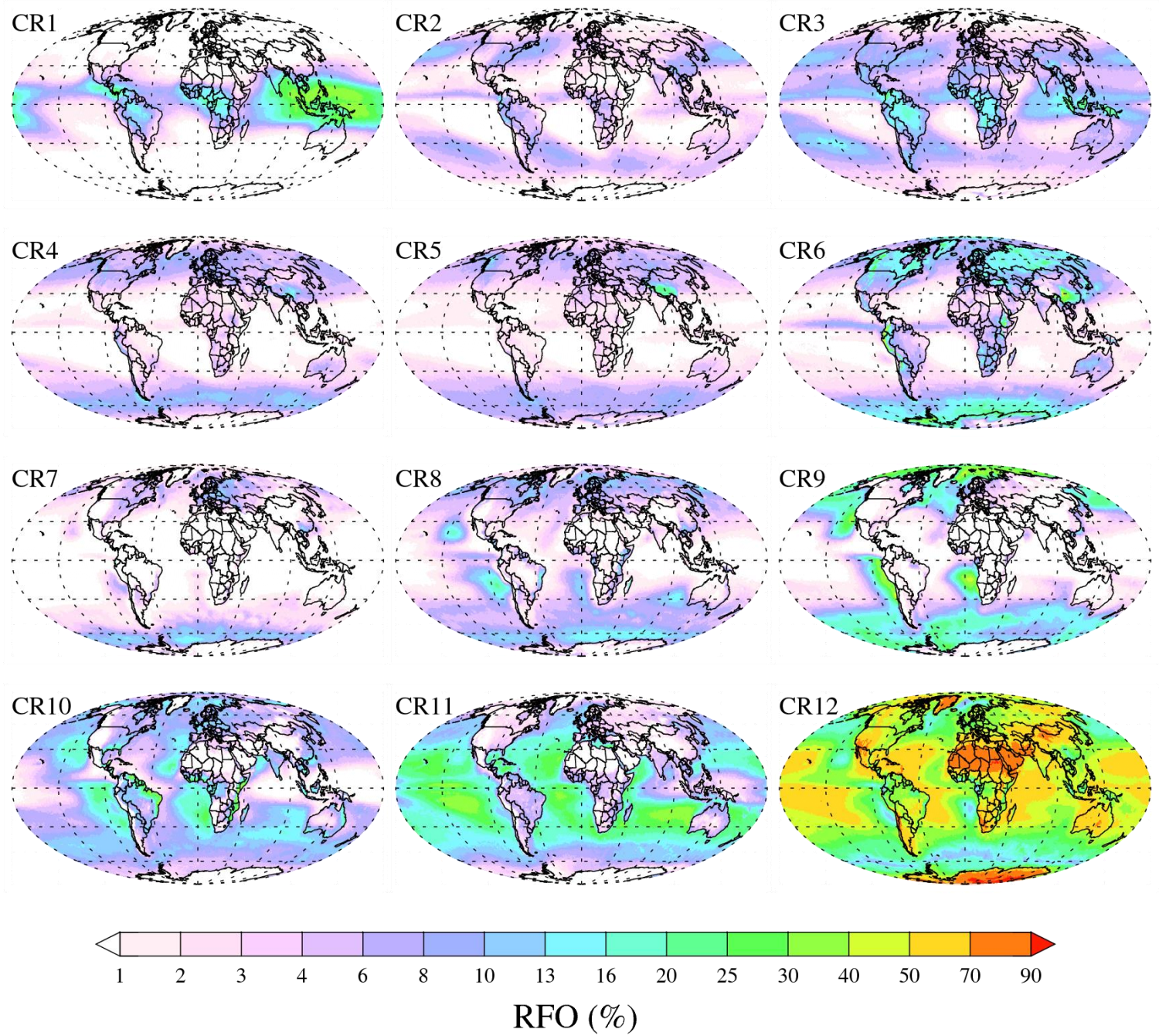
Our thinking

- 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"

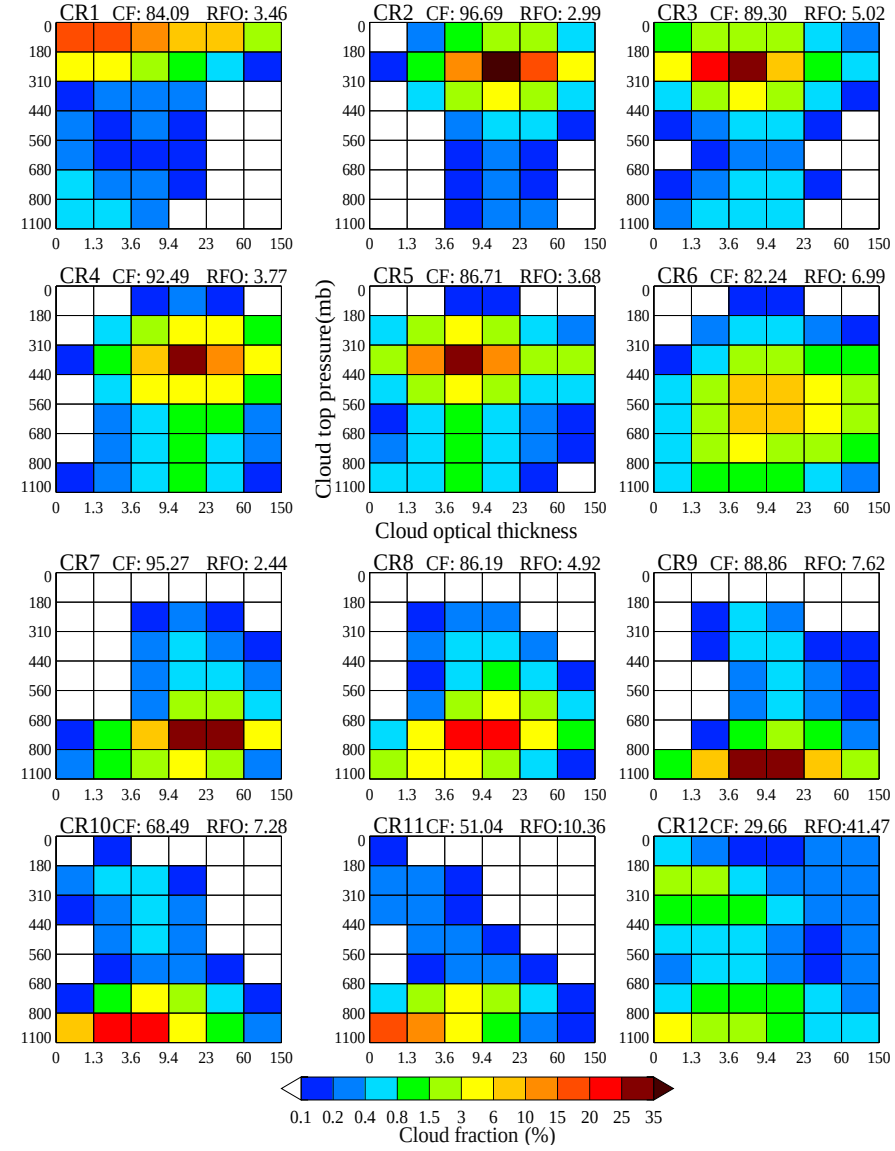
The 12 MODIS Collection 6 CRs

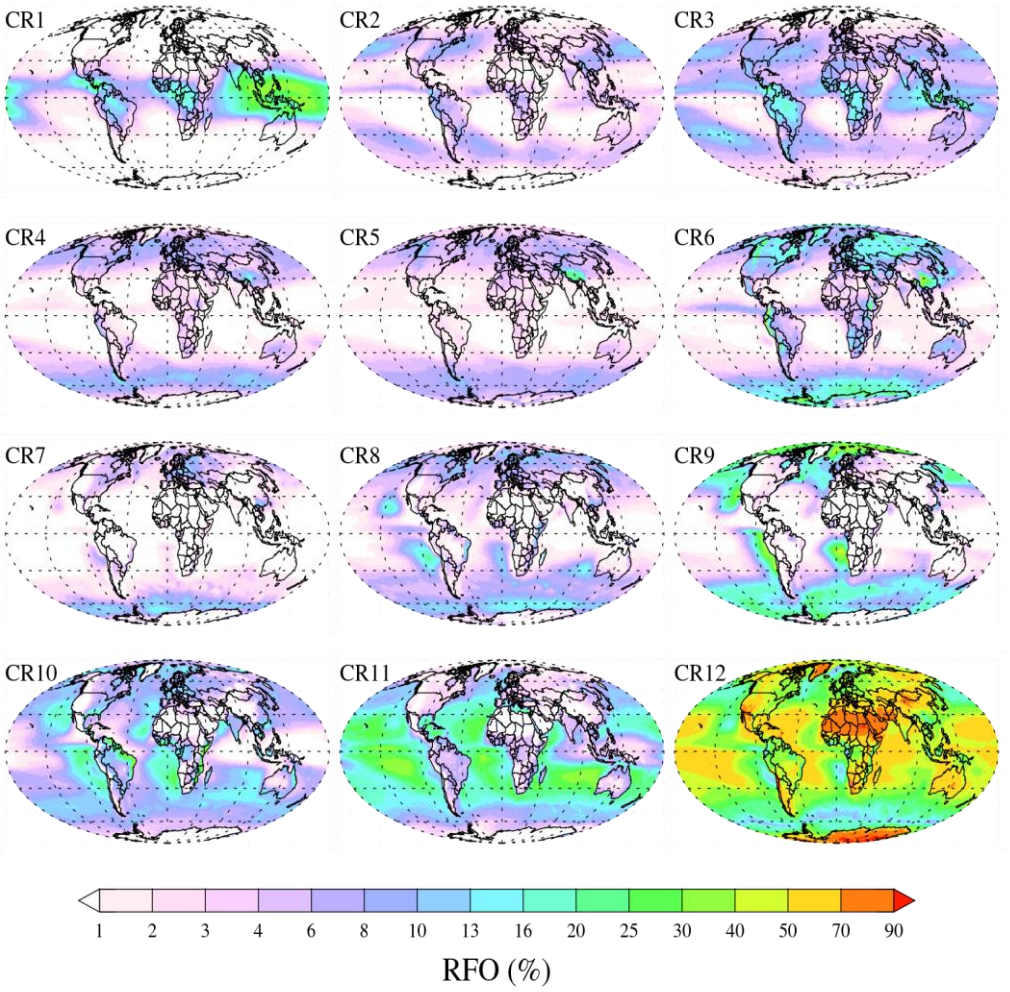


Where the CRs occur

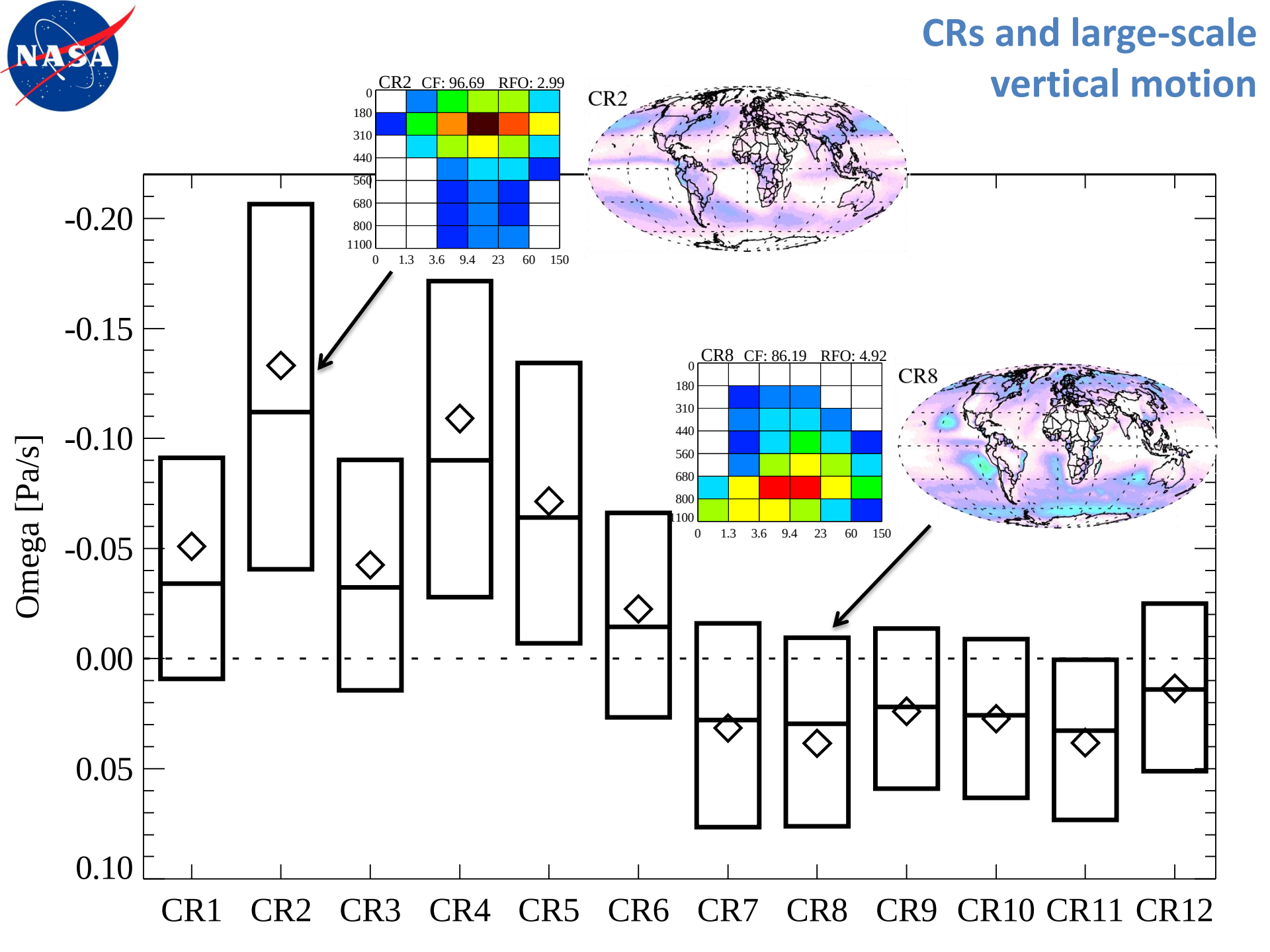


The full picture





CRs and large-scale vertical motion



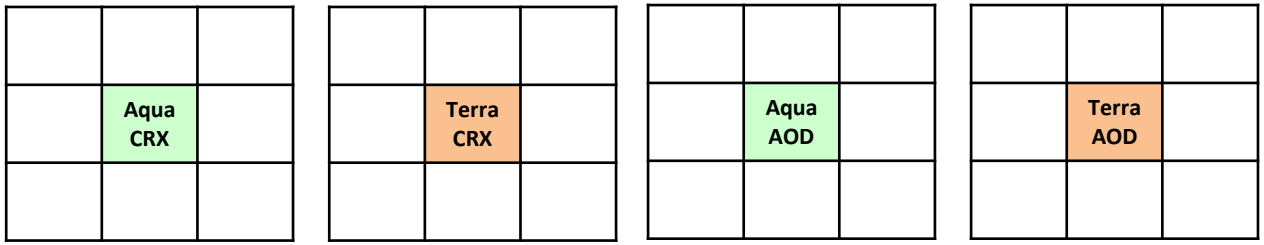
Dataset and methodology

- 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)

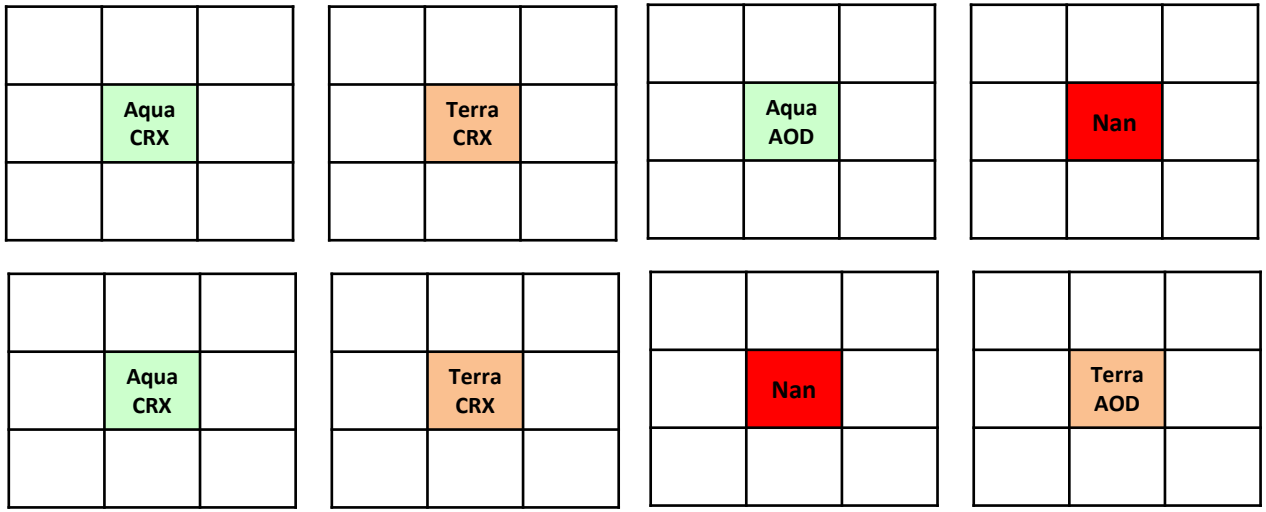
AOD Determination

1)



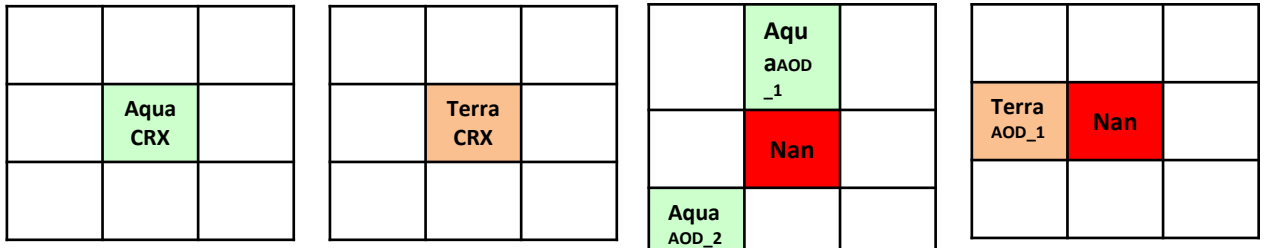
AOD = (Aqua AOD + Terra AOD) / 2.

2)



AOD = Aqua AOD OR AOD = Terra AOD

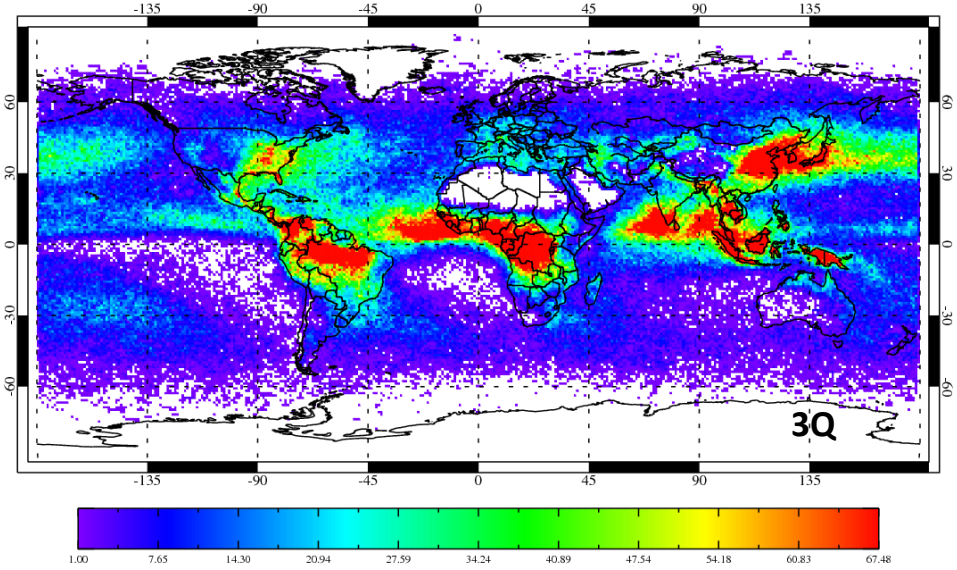
3)



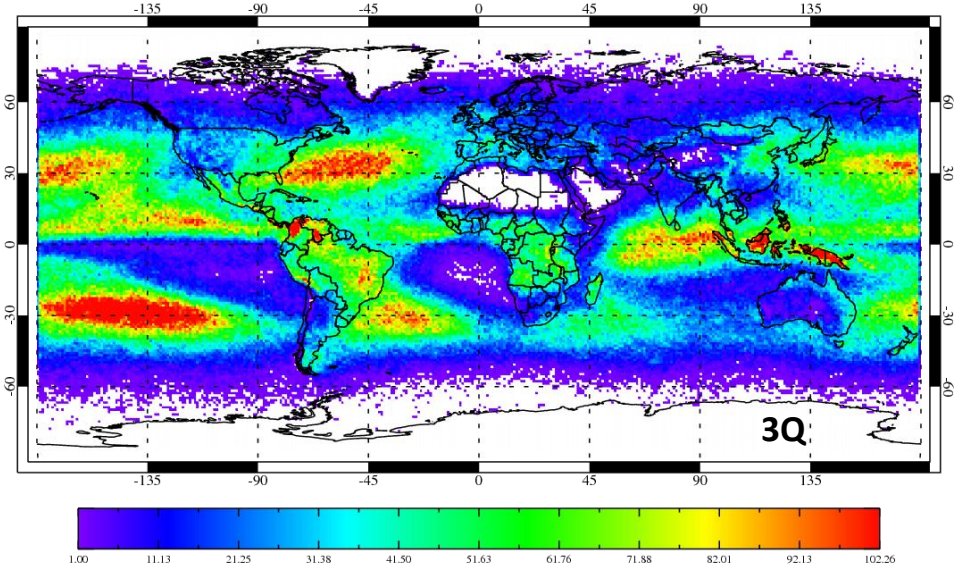
AOD = (Aqua_AOD_1+Aqua_AOD_2+Terra_AOD_1) / 3.

Comparison of two AOD sampling options (CR3)

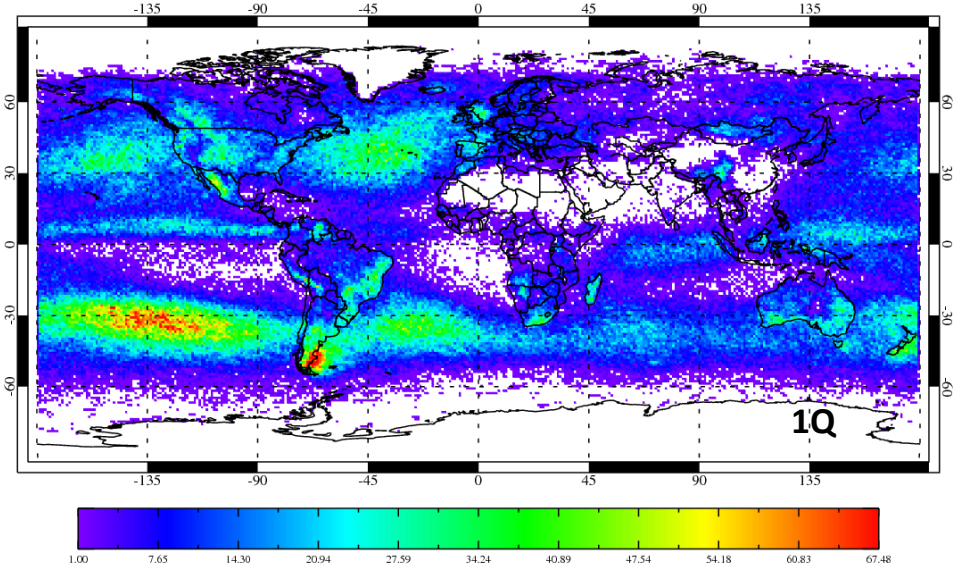
AOD distribution defined PER CR



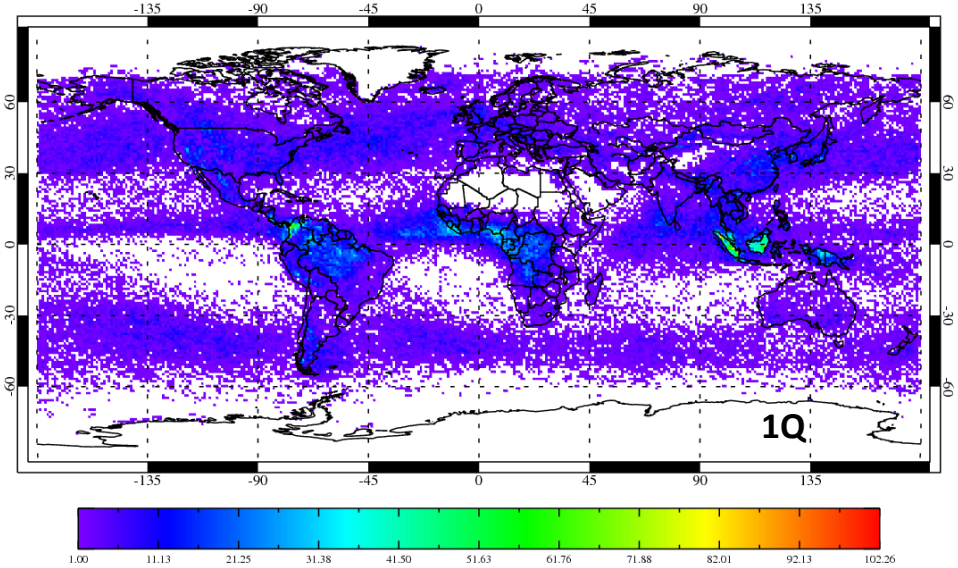
AOD distribution defined PER GRIDCELL

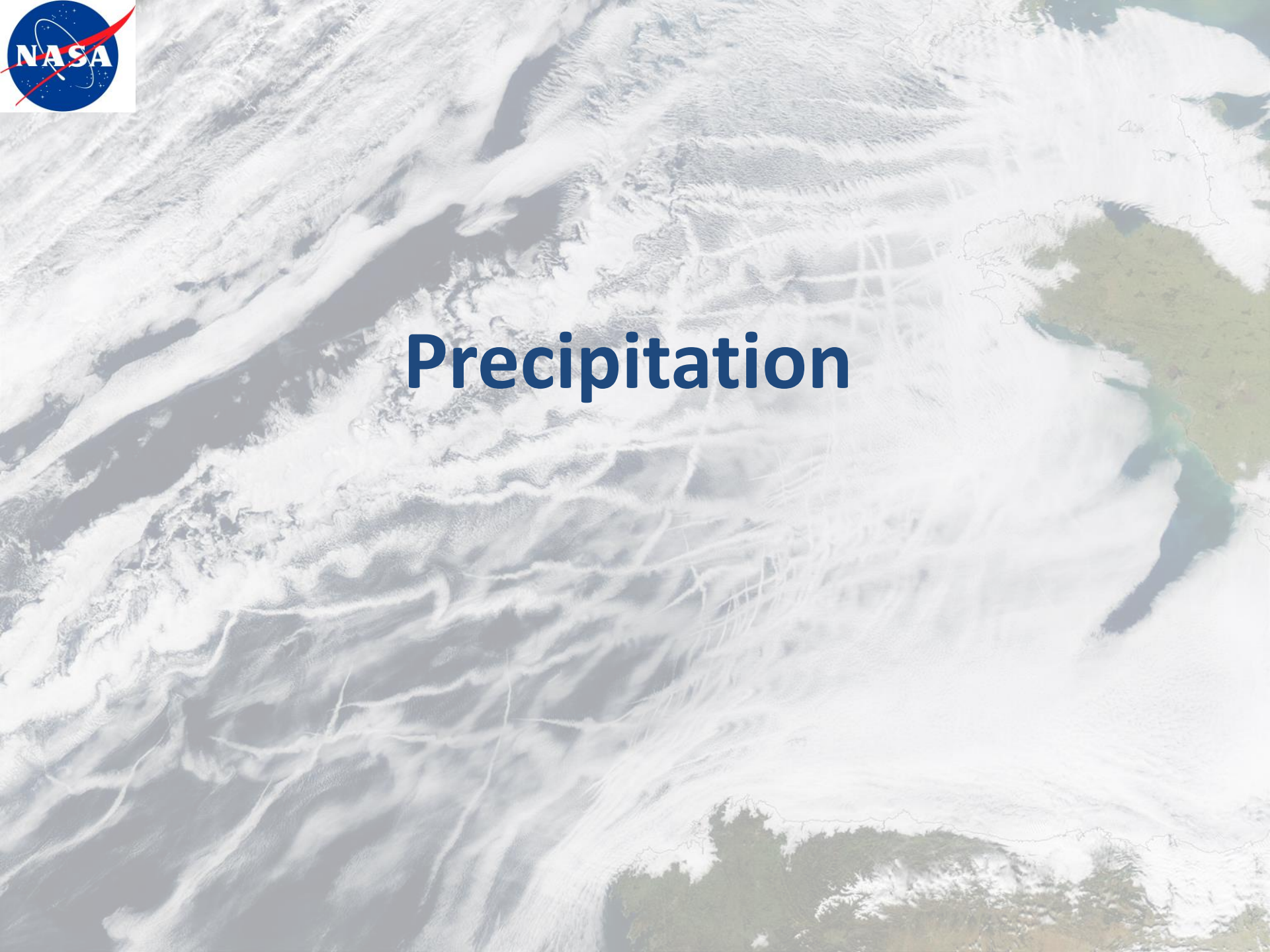


1Q AOD



1Q AOD

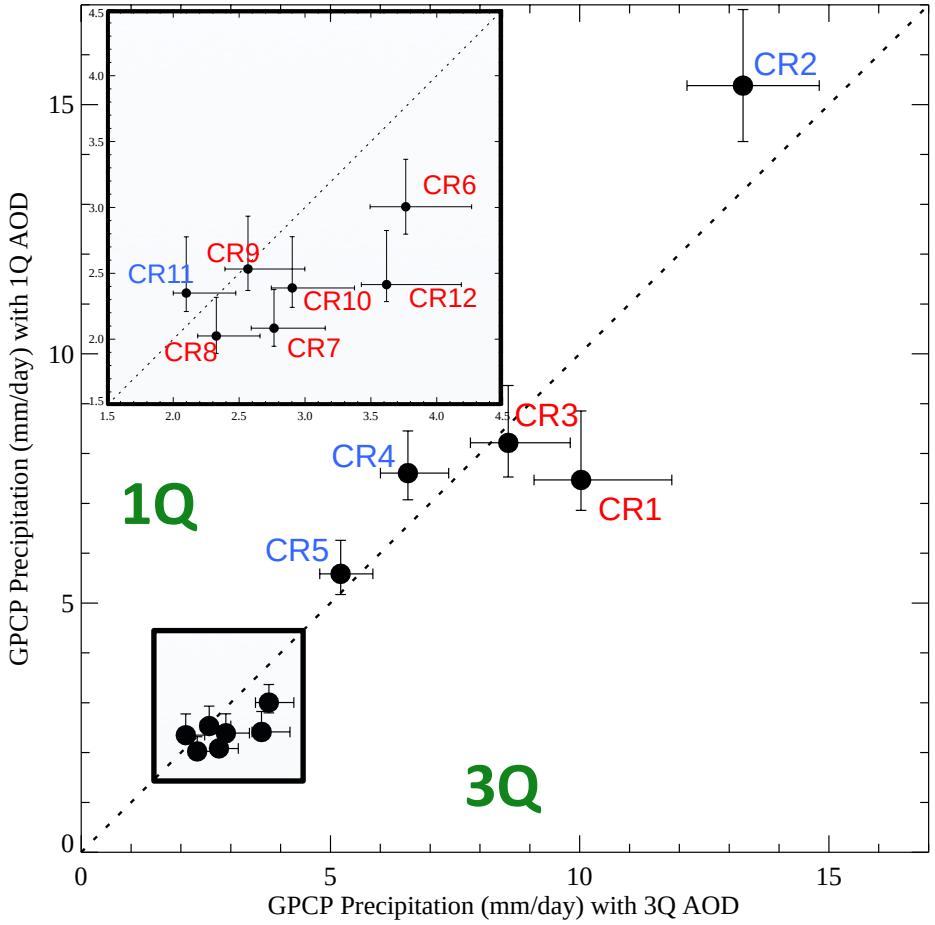




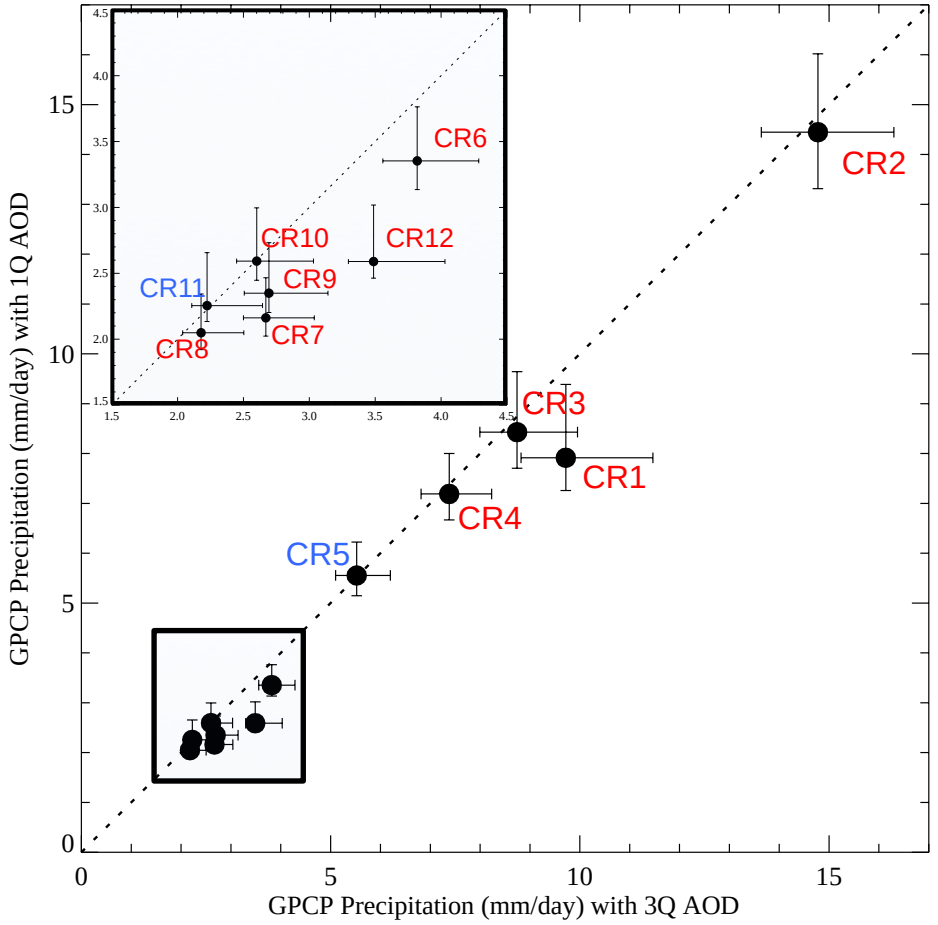
Precipitation

Precipitation comparison (RR>0) two sampling methods

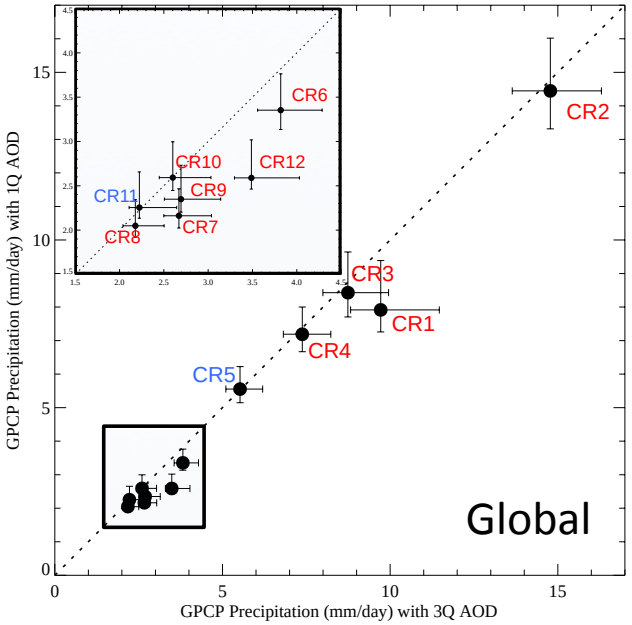
3Q/1Q AOD defined by per CR per Season

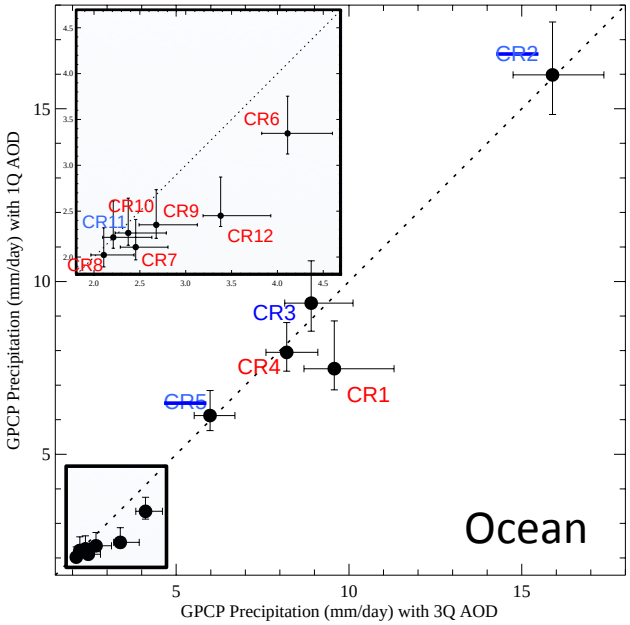


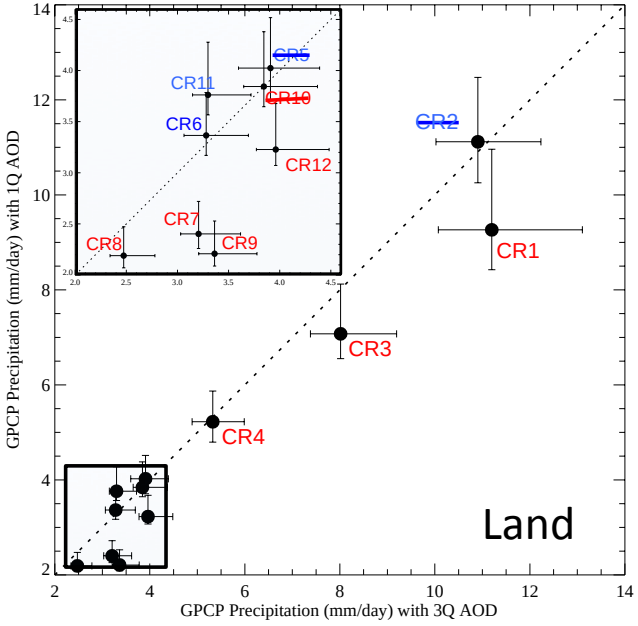
3Q/1Q AOD defined by per Grid per Season



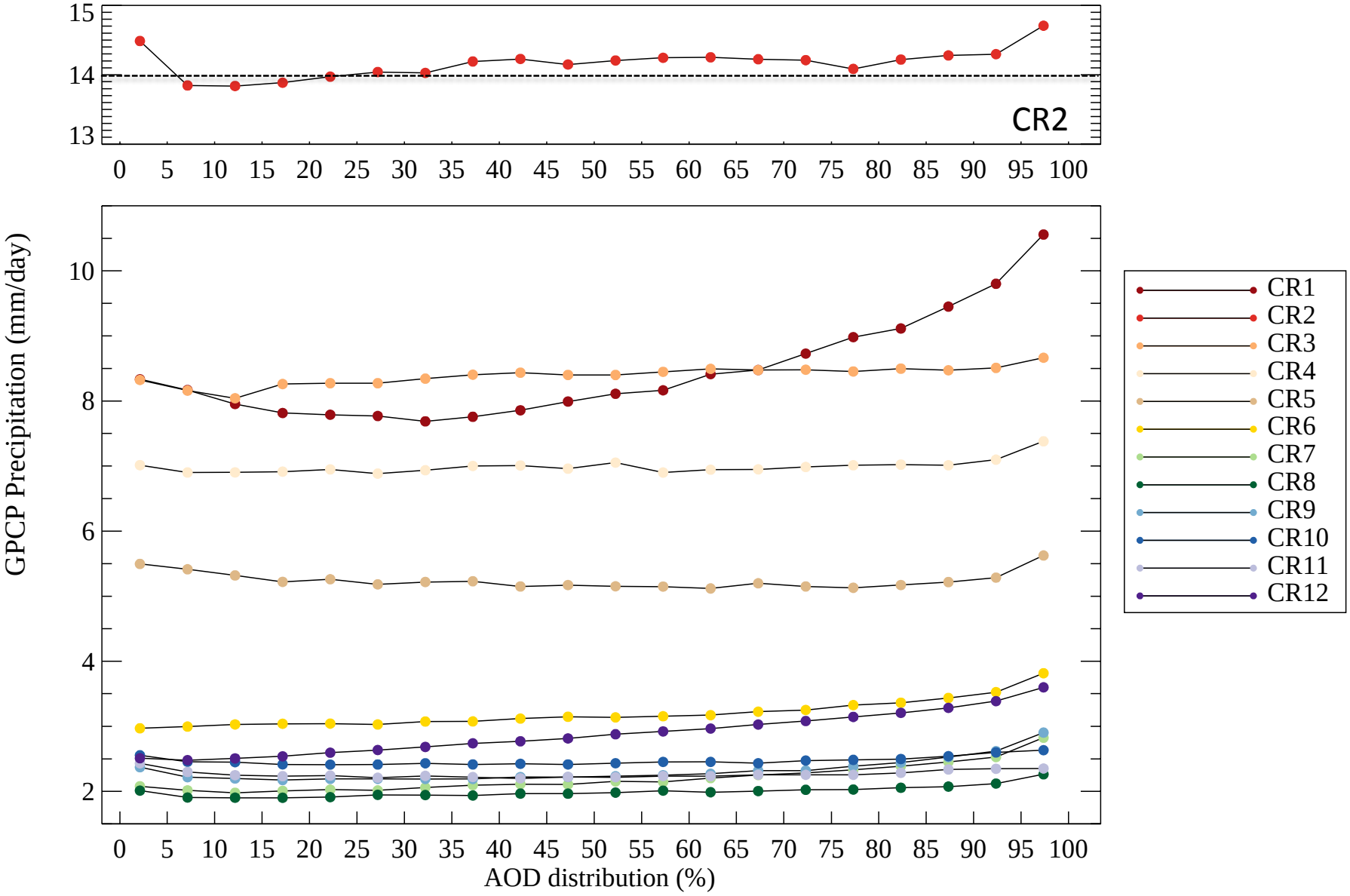
Precipitation (RR>0) comparison (Land-Ocean)

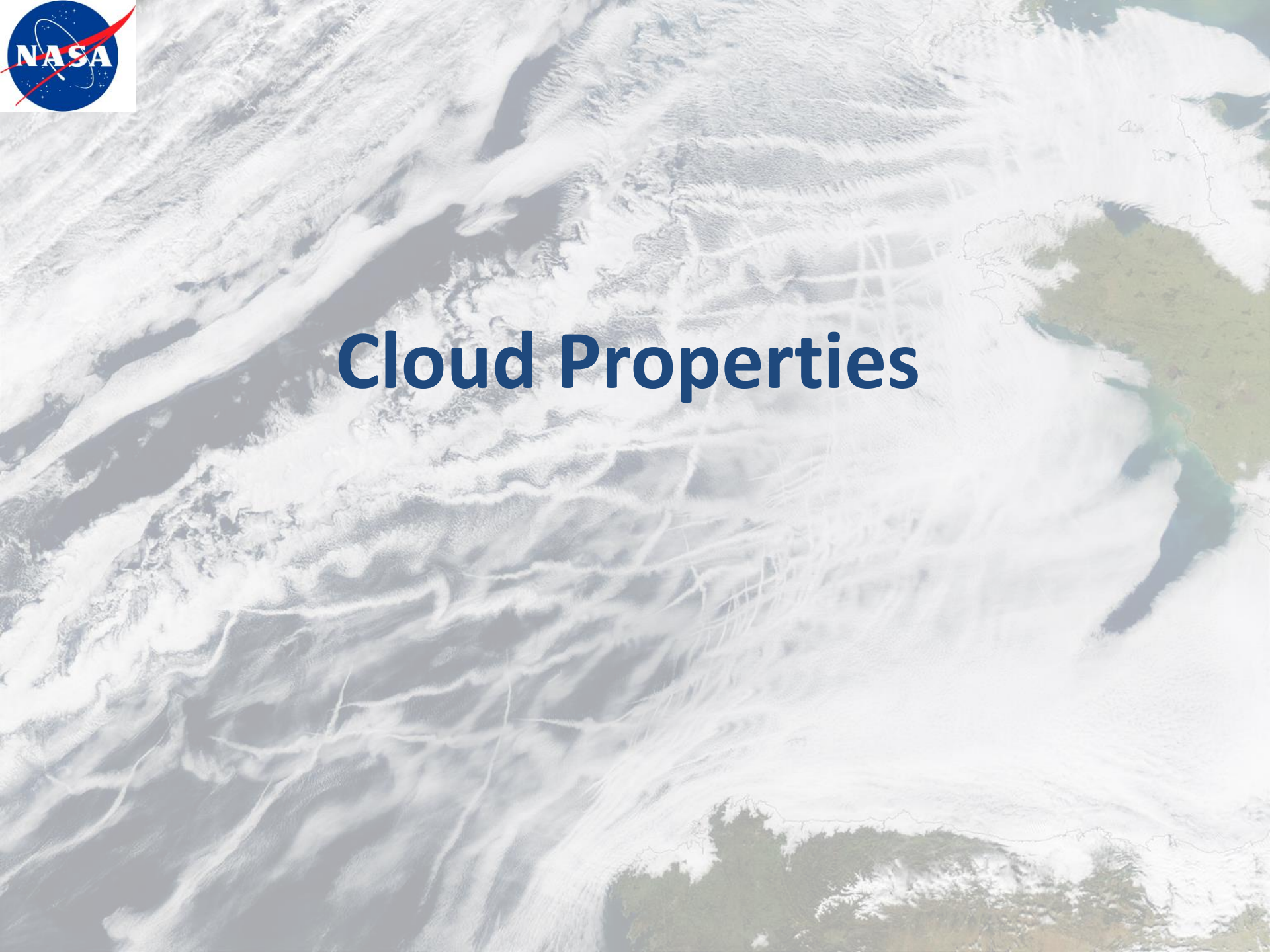






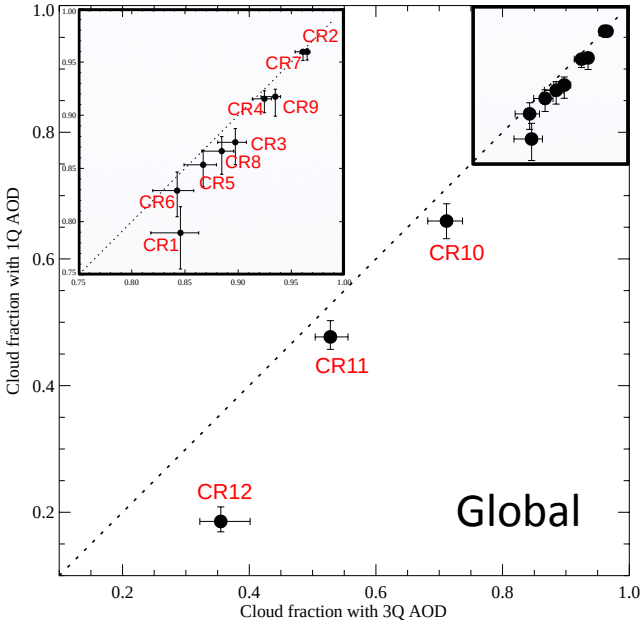
Precipitation (RR>0) vs AOD percentile



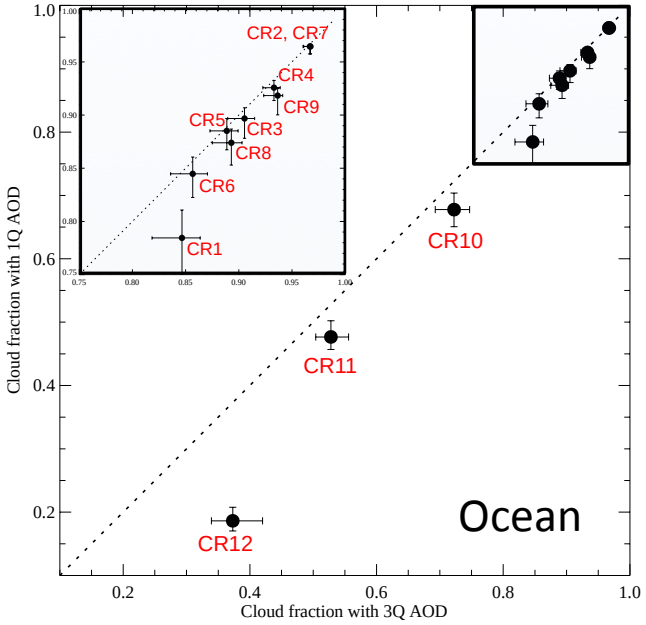


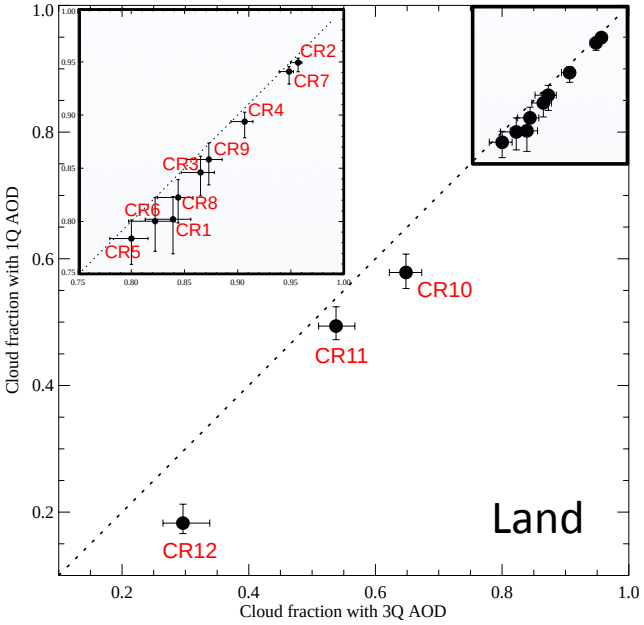
Cloud Properties

Cloud fraction

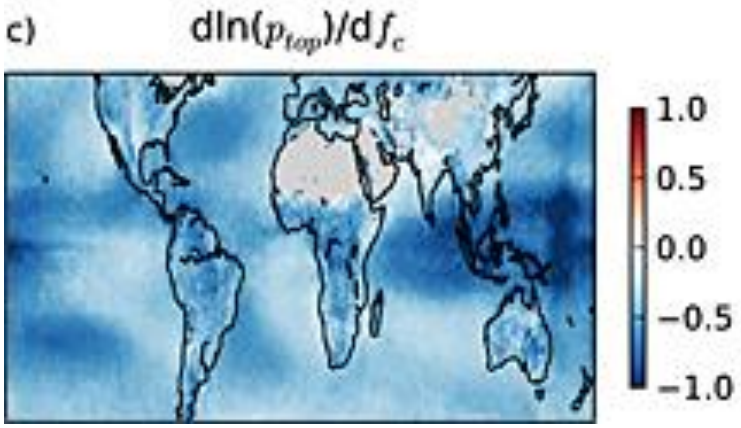


Red=meets expectations

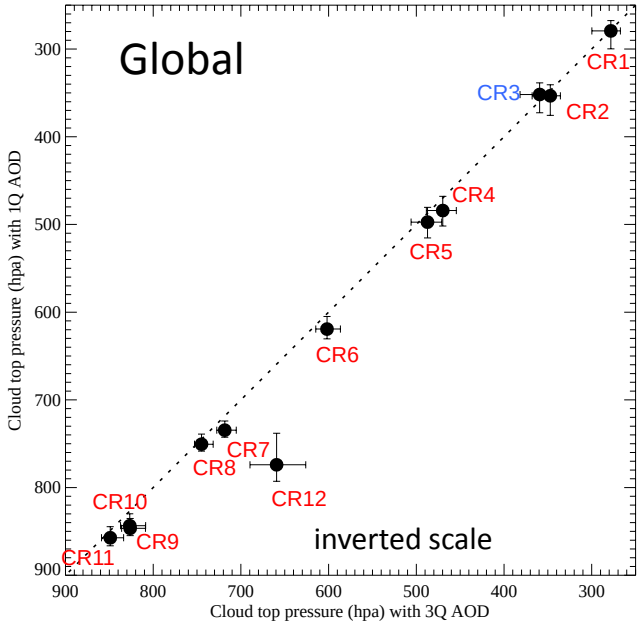


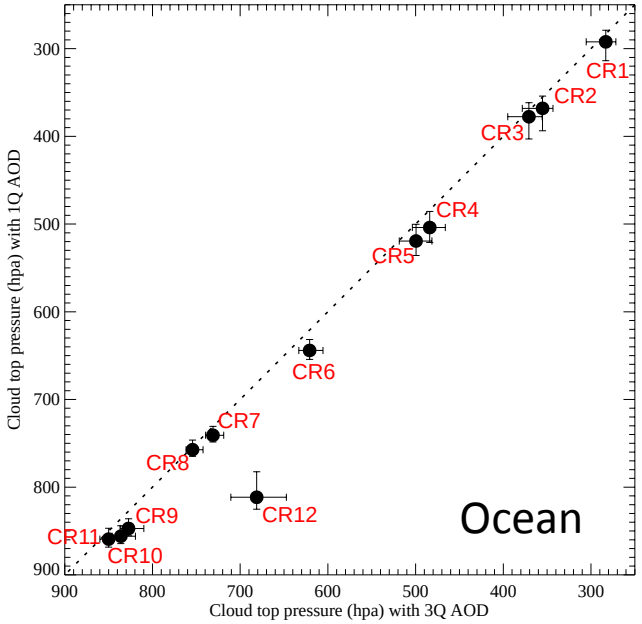


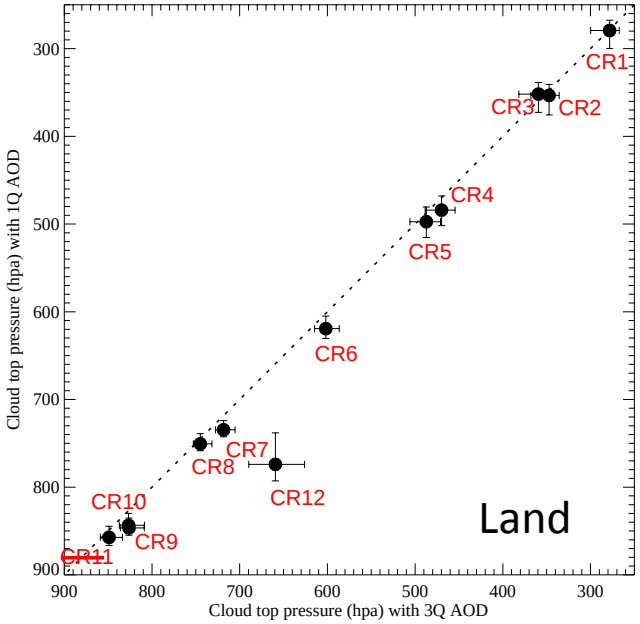
(Gryspeerdt et al. 2014)



Cloud Top Pressure

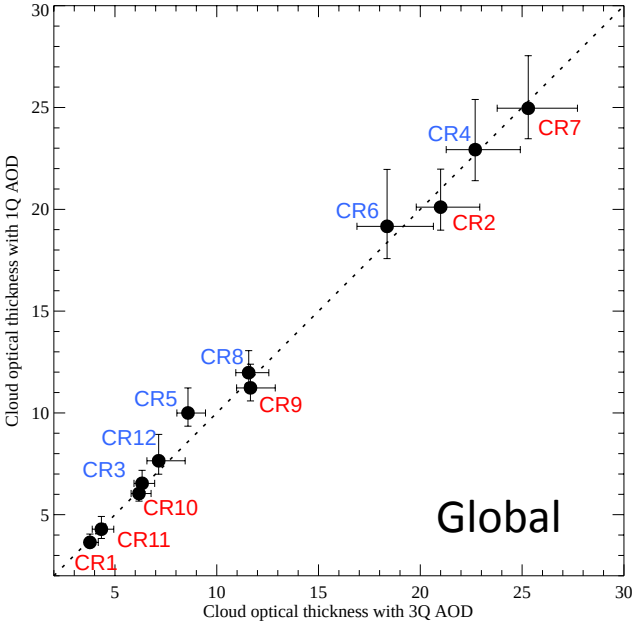


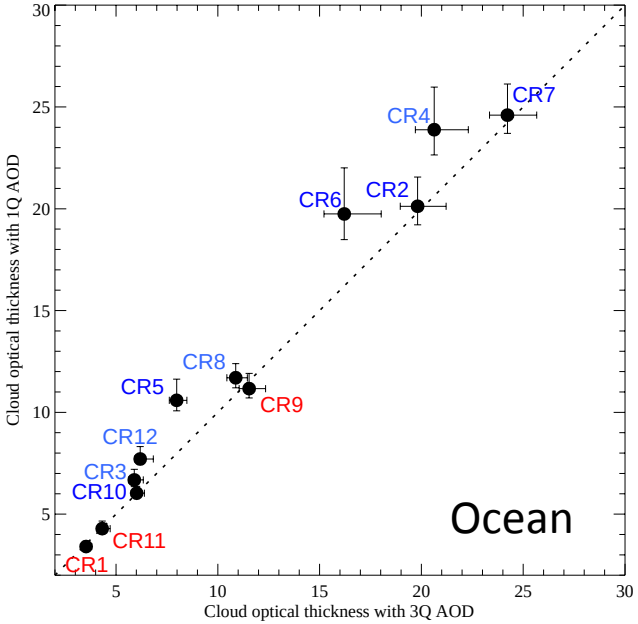


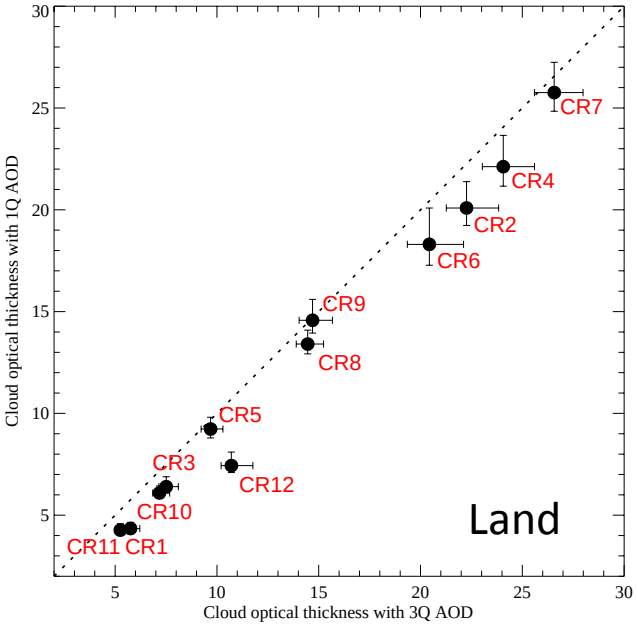


Cloud optical thickness

Red=meets expectations

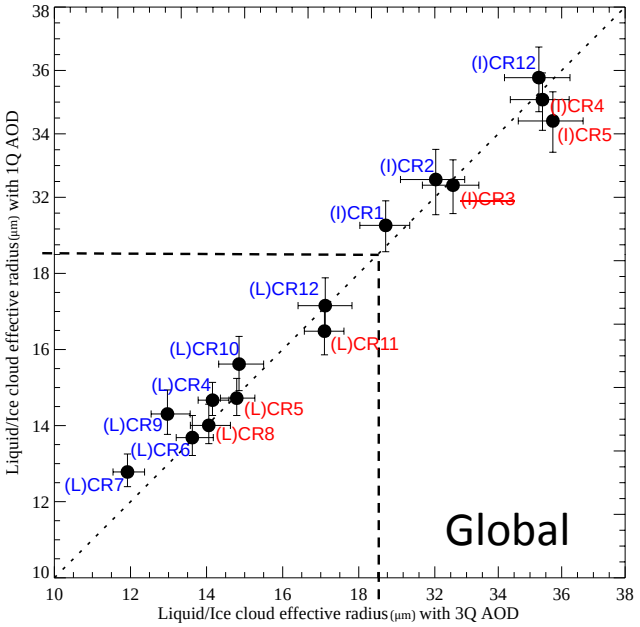


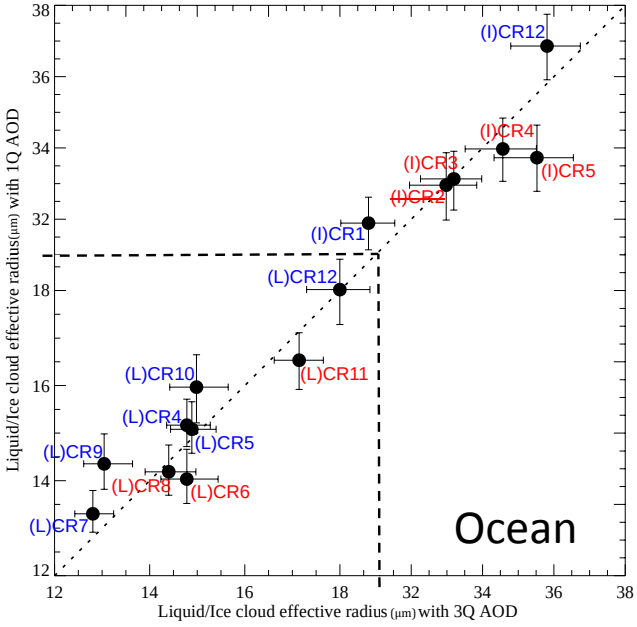


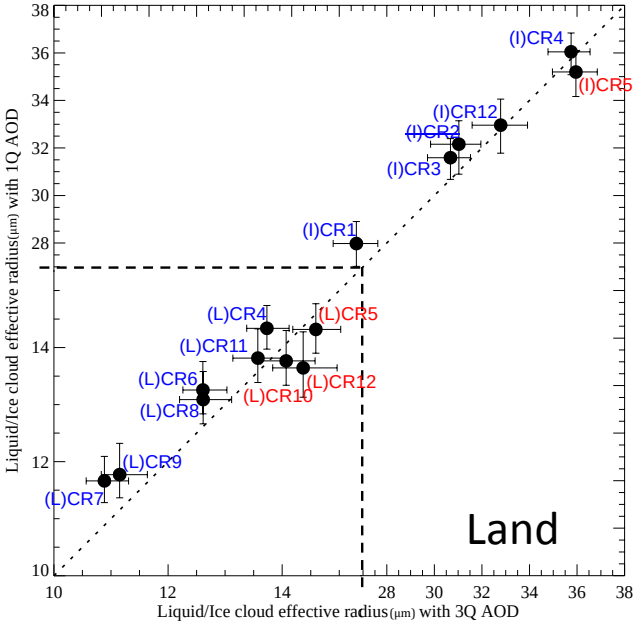


Cloud effective radius

Blue=meets expectations





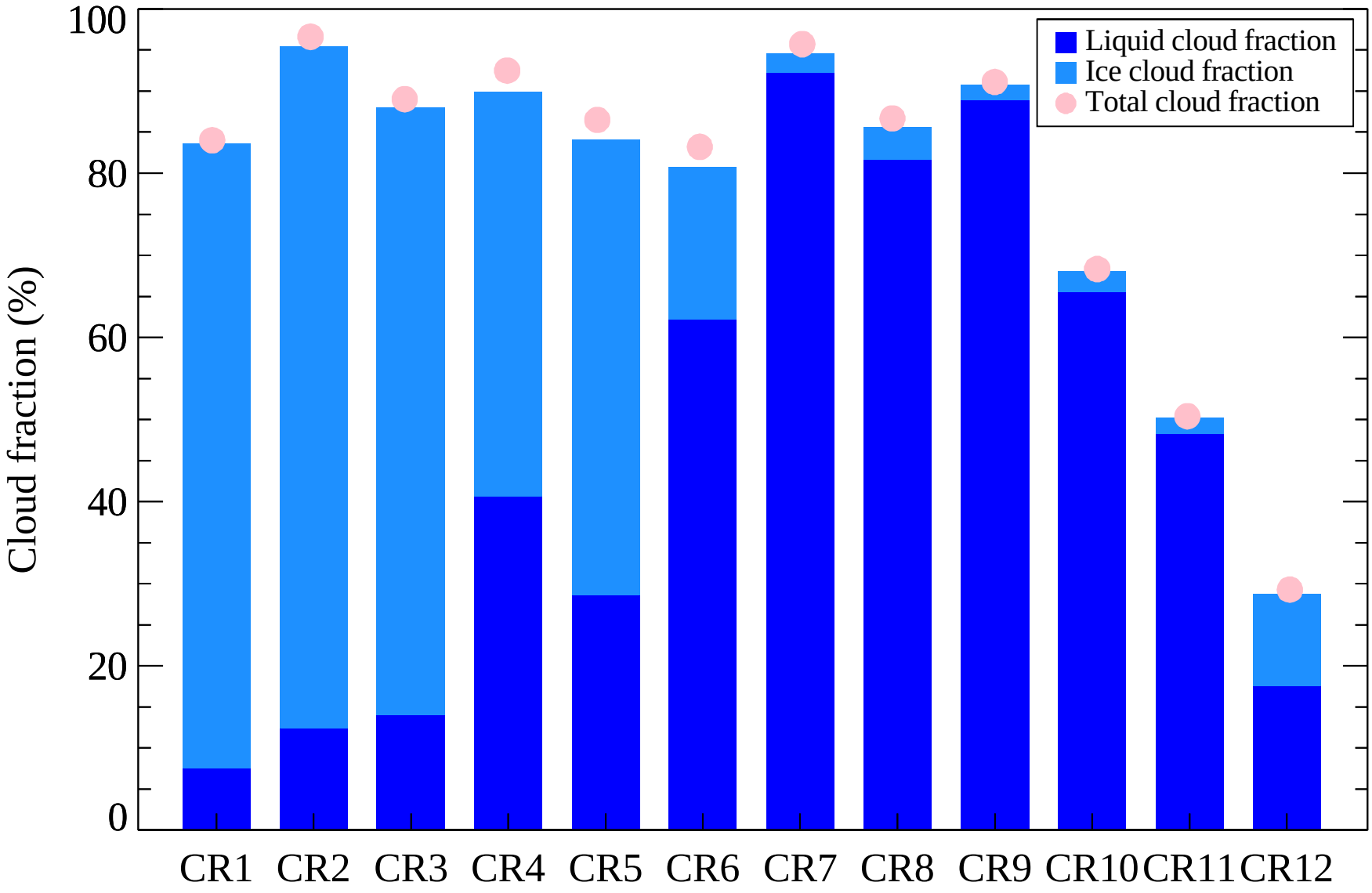


Summary and parting thoughts

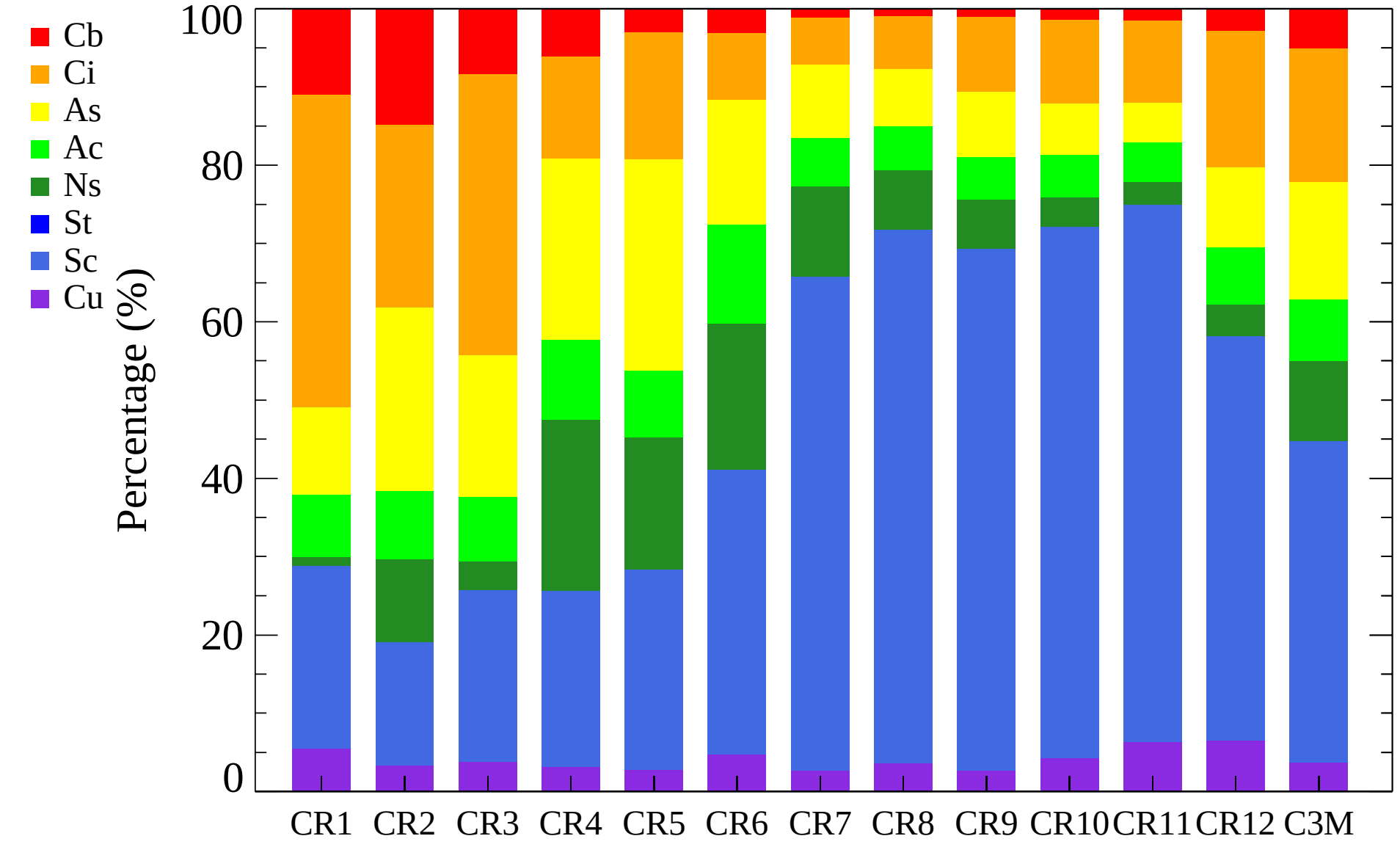
- We propose that Aerosol-Cloud-Precipitation relationships be examined on a “cloud regime” basis
  - This helps us examine aerosol influence under more “similar” conditions
- Even then, the outcomes depend on how one samples AOD distributions (weaker or stronger constraints on meteorology)
- Most times,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

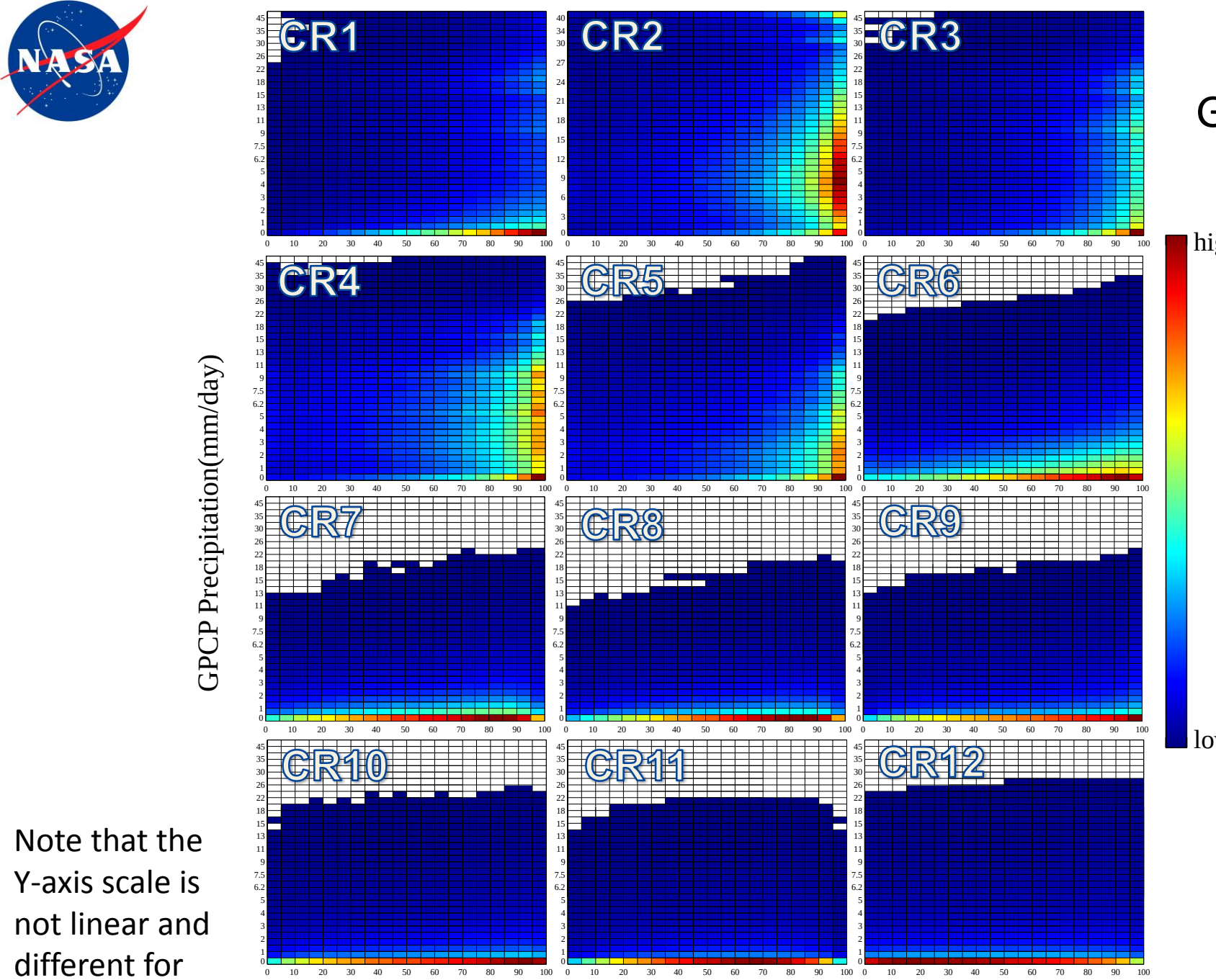
Additional Slides

CR thermodynamic phase



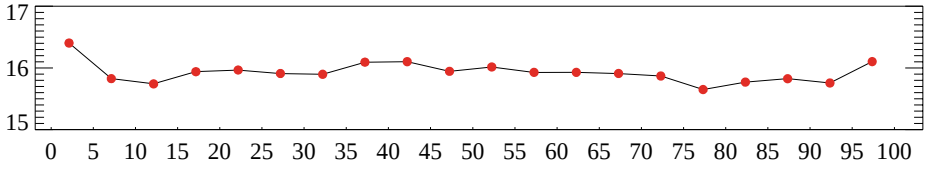
CR cloud type breakdown per CloudSat



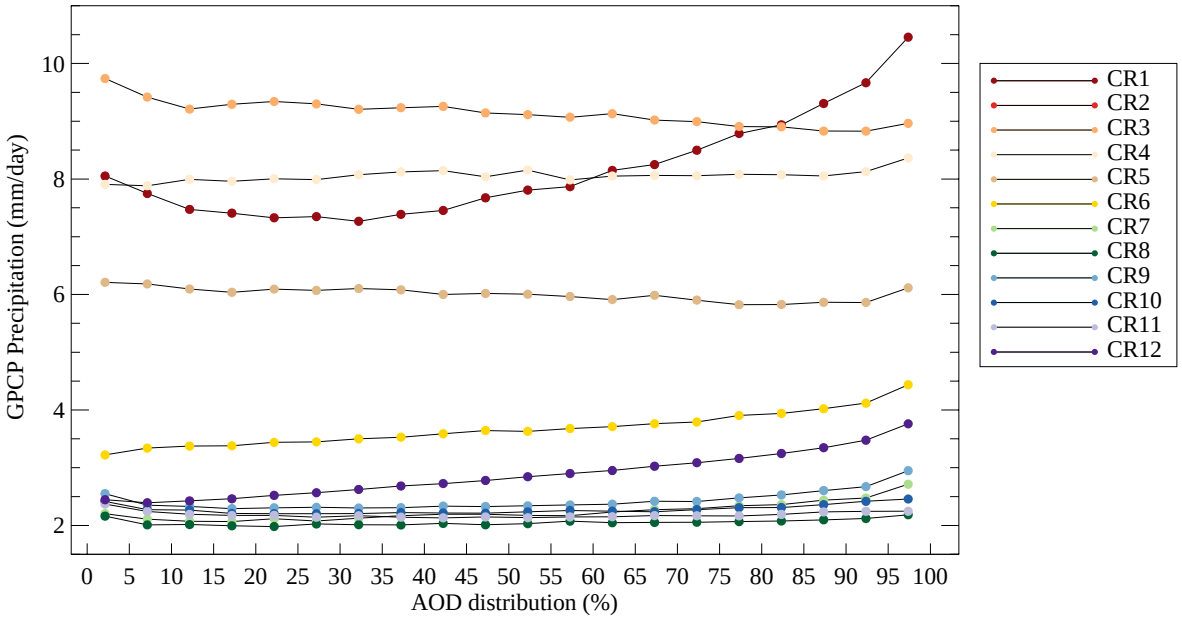


Global

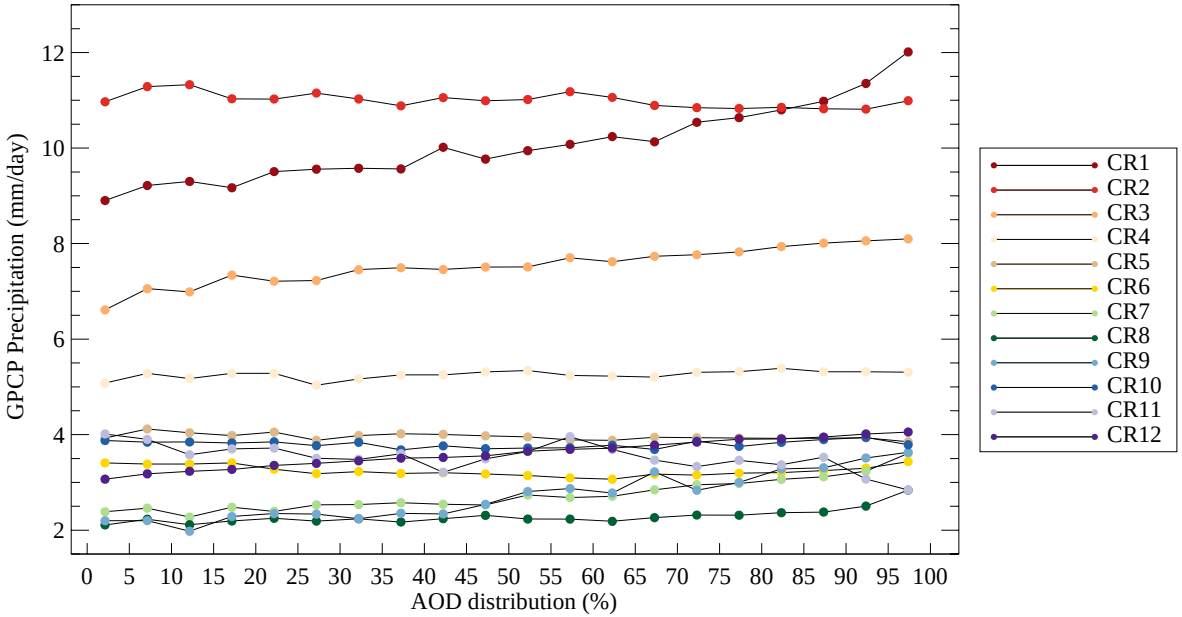
Note that the Y-axis scale is not linear and different for CR2.

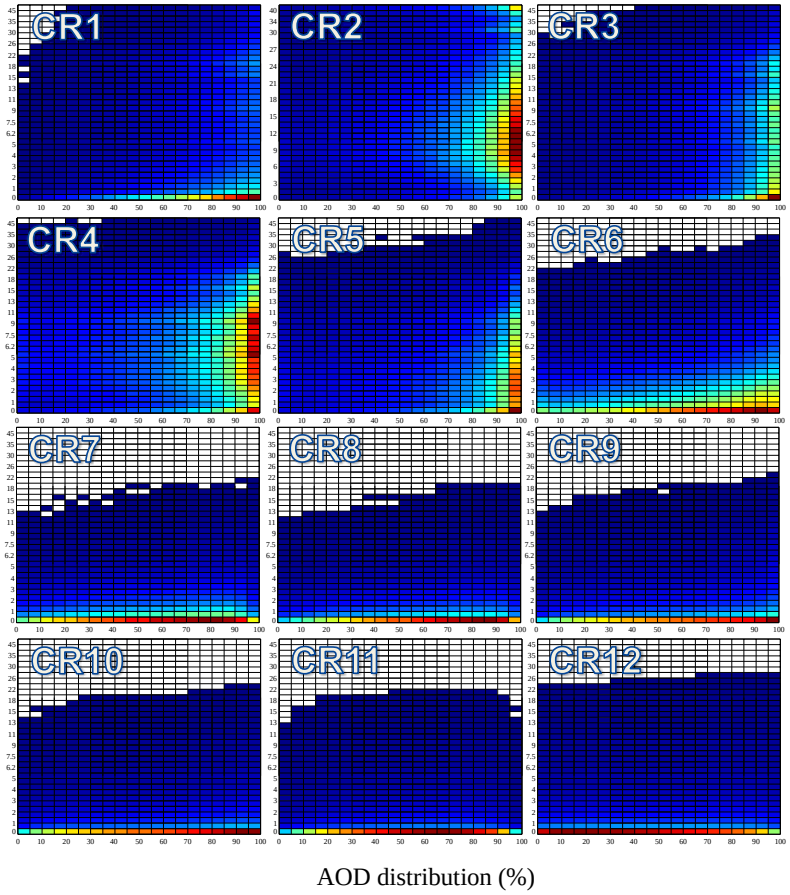

17
16
15
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

Ocean

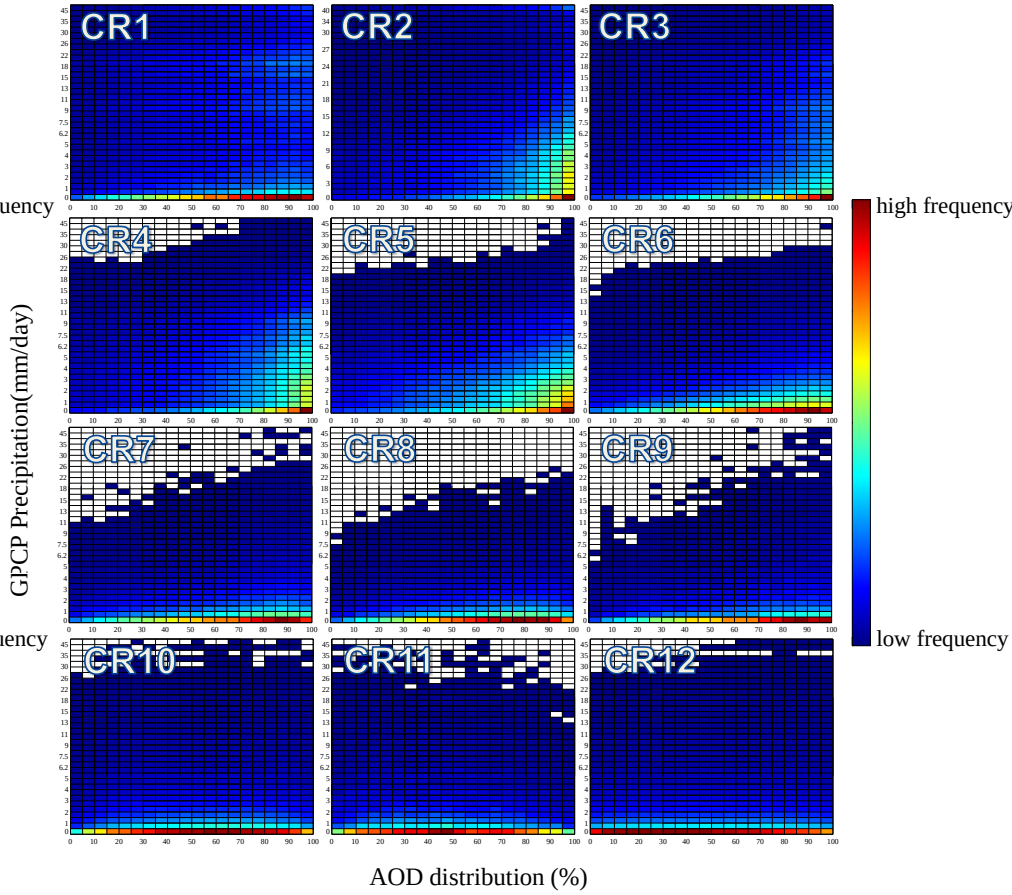

GPCP Precipitation (mm/day)
10
8
6
4
2
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
AOD distribution (%)
CR1
CR2
CR3
CR4
CR5
CR6
CR7
CR8
CR9
CR10
CR11
CR12

Land


GPCP Precipitation (mm/day)
12
10
8
6
4
2
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
AOD distribution (%)
CR1
CR2
CR3
CR4
CR5
CR6
CR7
CR8
CR9
CR10
CR11
CR12

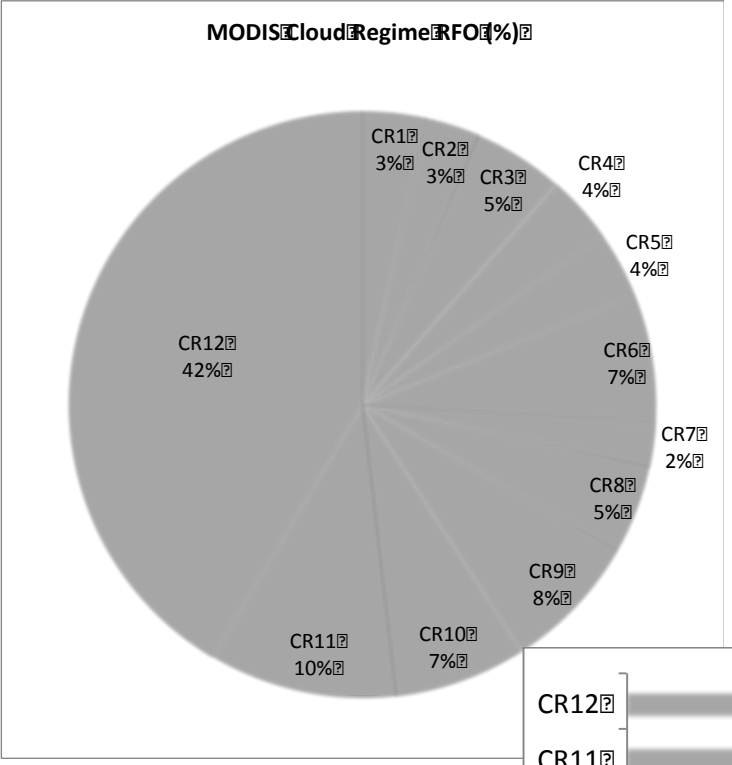


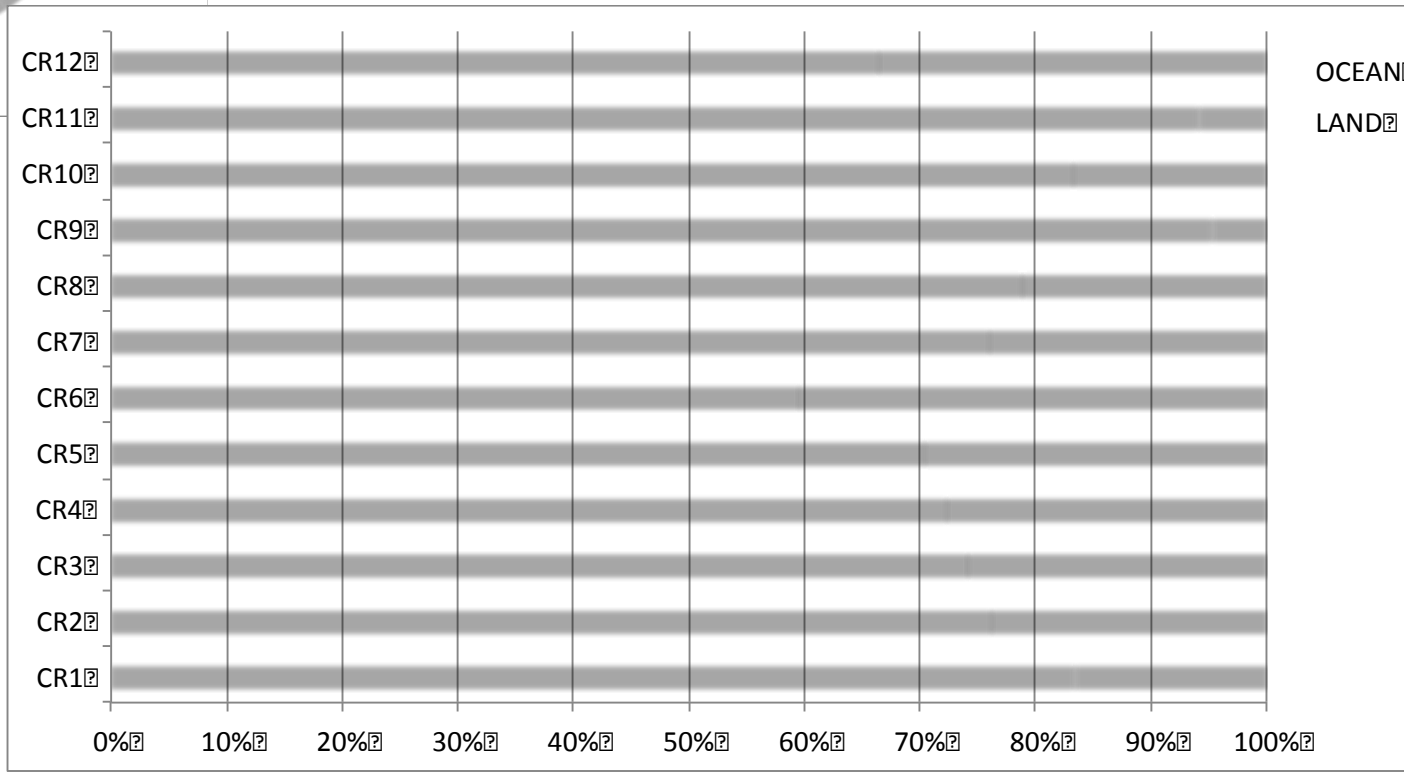
Ocean



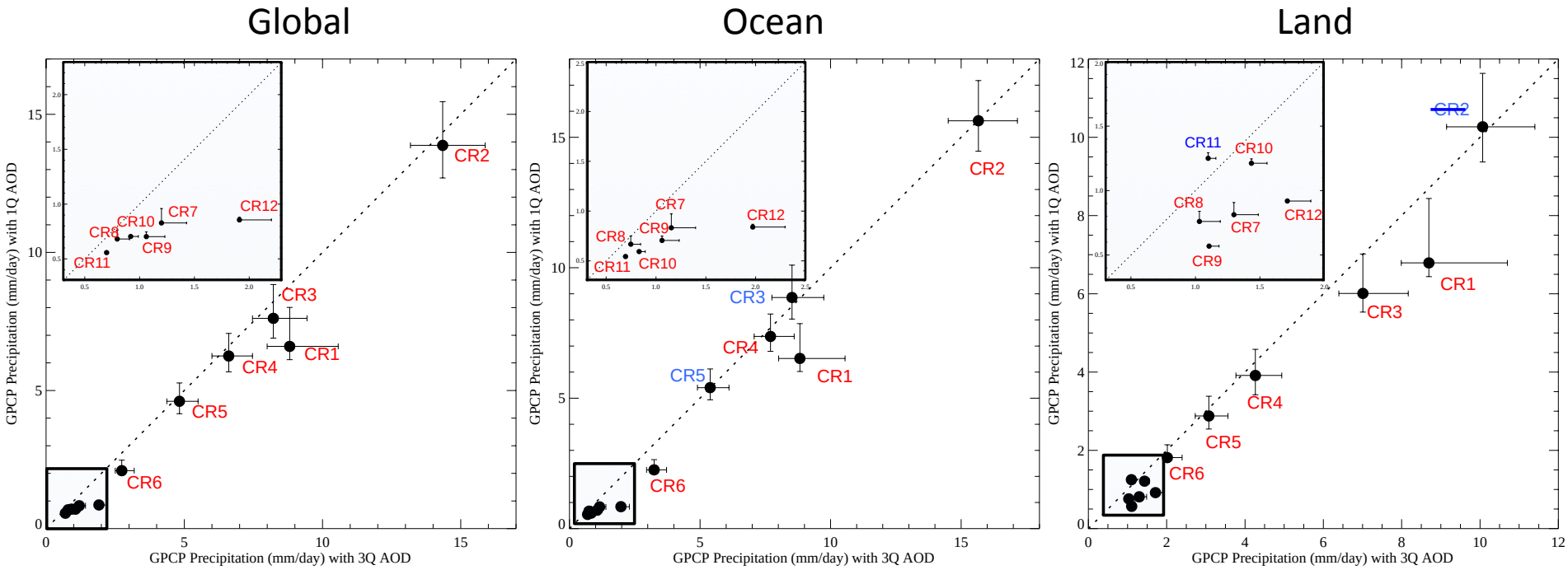
Land

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


MODIS Cloud Regime RFO (%)
CR1 3%
CR2 3%
CR3 5%
CR4 4%
CR5 4%
CR6 7%
CR7 2%
CR8 5%
CR9 8%
CR10 7%
CR11 10%
CR12 42%


CR12
CR11
CR10
CR9
CR8
CR7
CR6
CR5
CR4
CR3
CR2
CR1
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
OCEAN
LAND

GPCP daily mean Precipitation (P>=0)

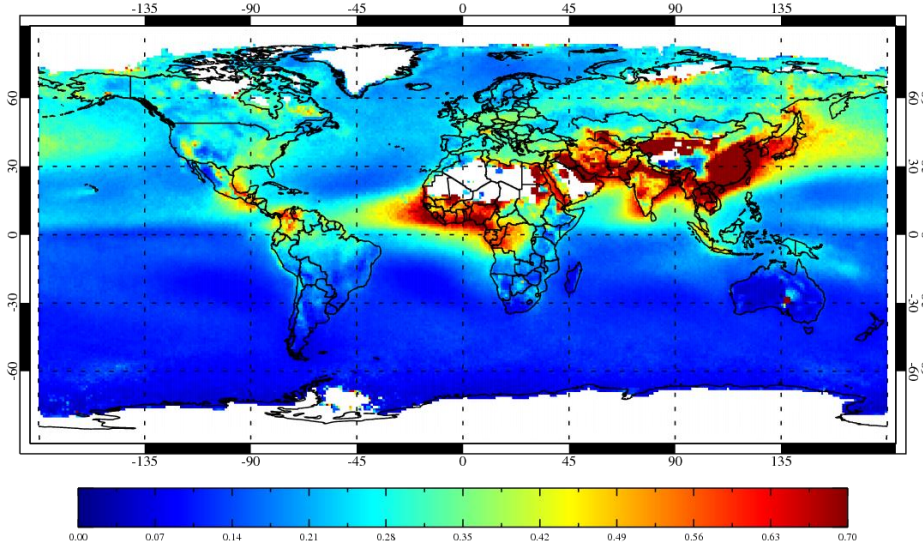


Scatter plot comparing Latitudinally-weighted mean precipitation rate(*including zero* precipitation) for upper 3q AOD and lower 1q AOD. The horizontal and vertical error bars indicate one fifth of the interquartile range of the distributions used to calculate the composite means; distance **from median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

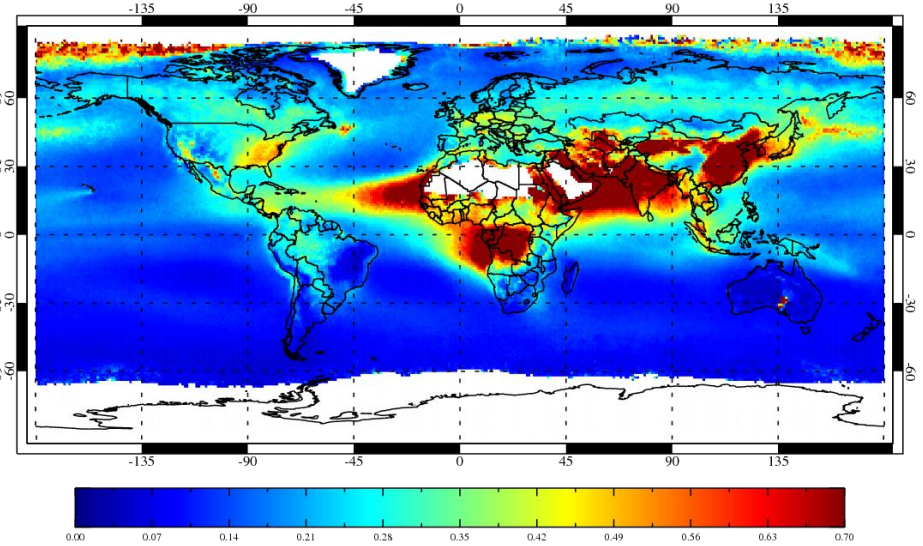
(MYD CR = MOD CR) + daily grid new AOD + daily mean GPCP

Assigned 3Q AOD

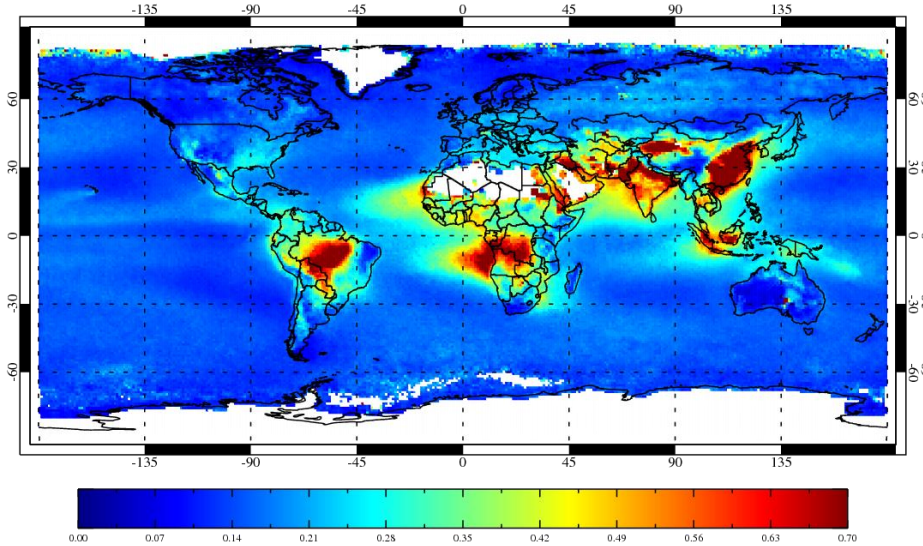
MAM



JJA

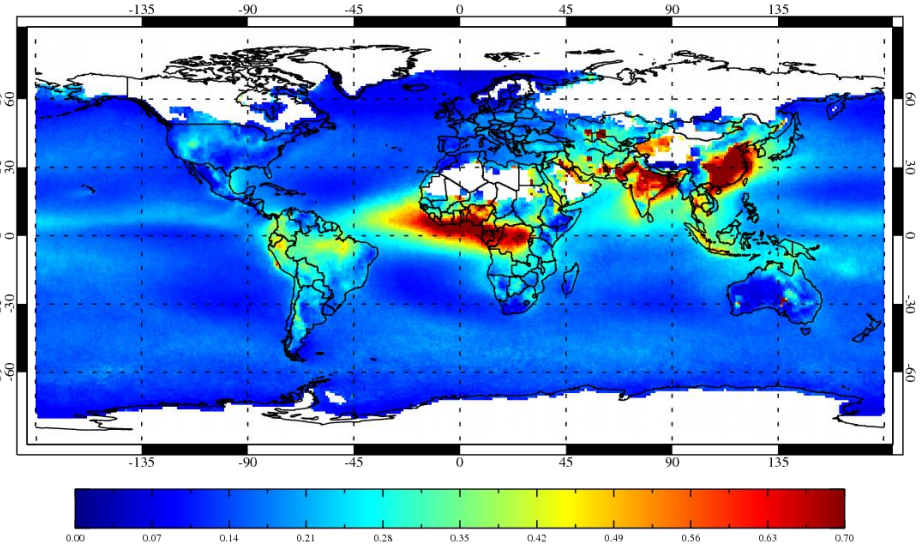


SON



AOD

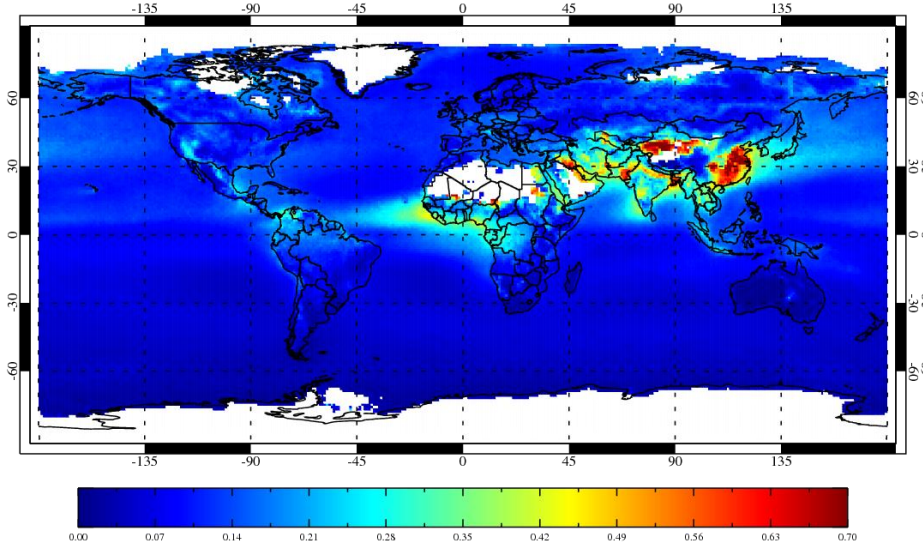
DJF



AOD

Assigned 1Q AOD

MAM



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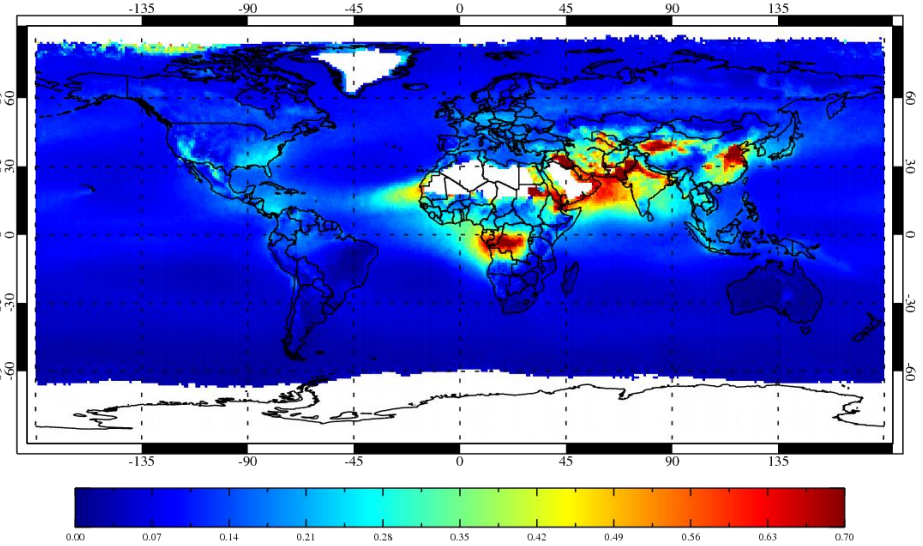
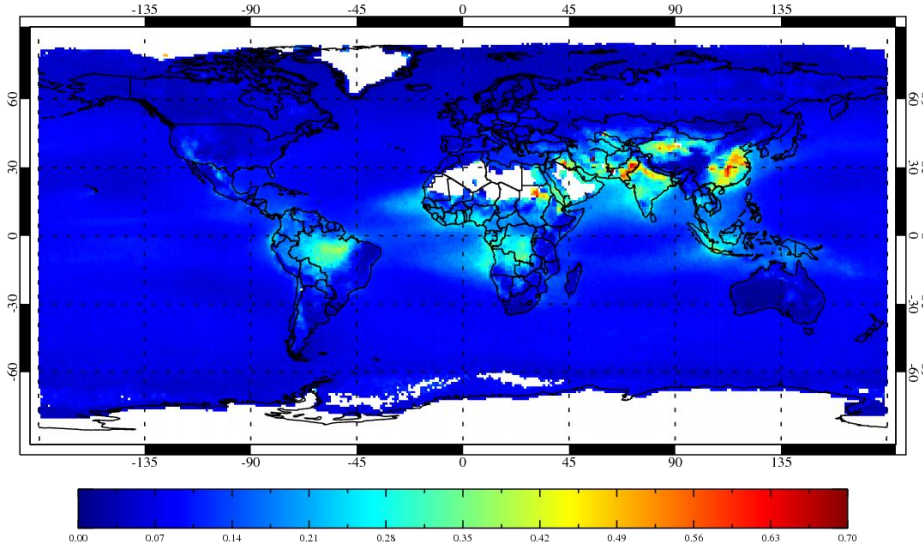
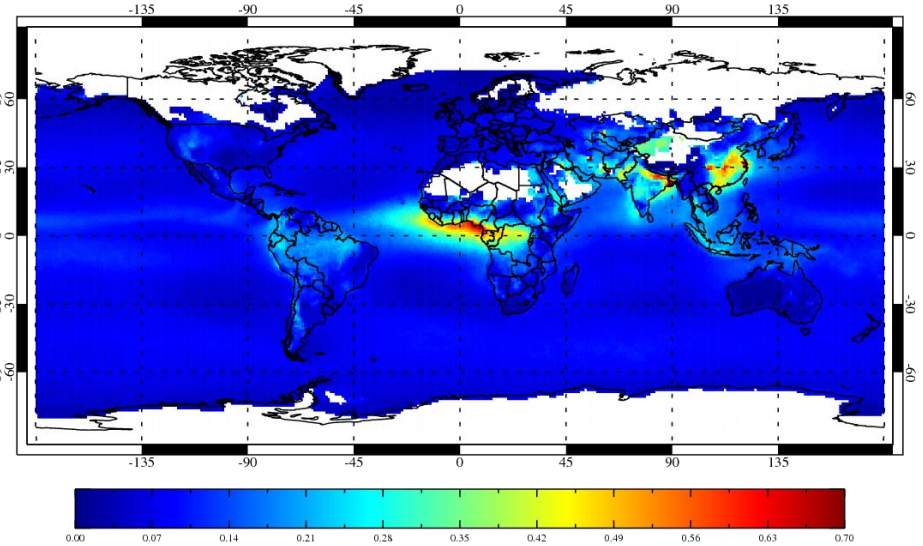


SON

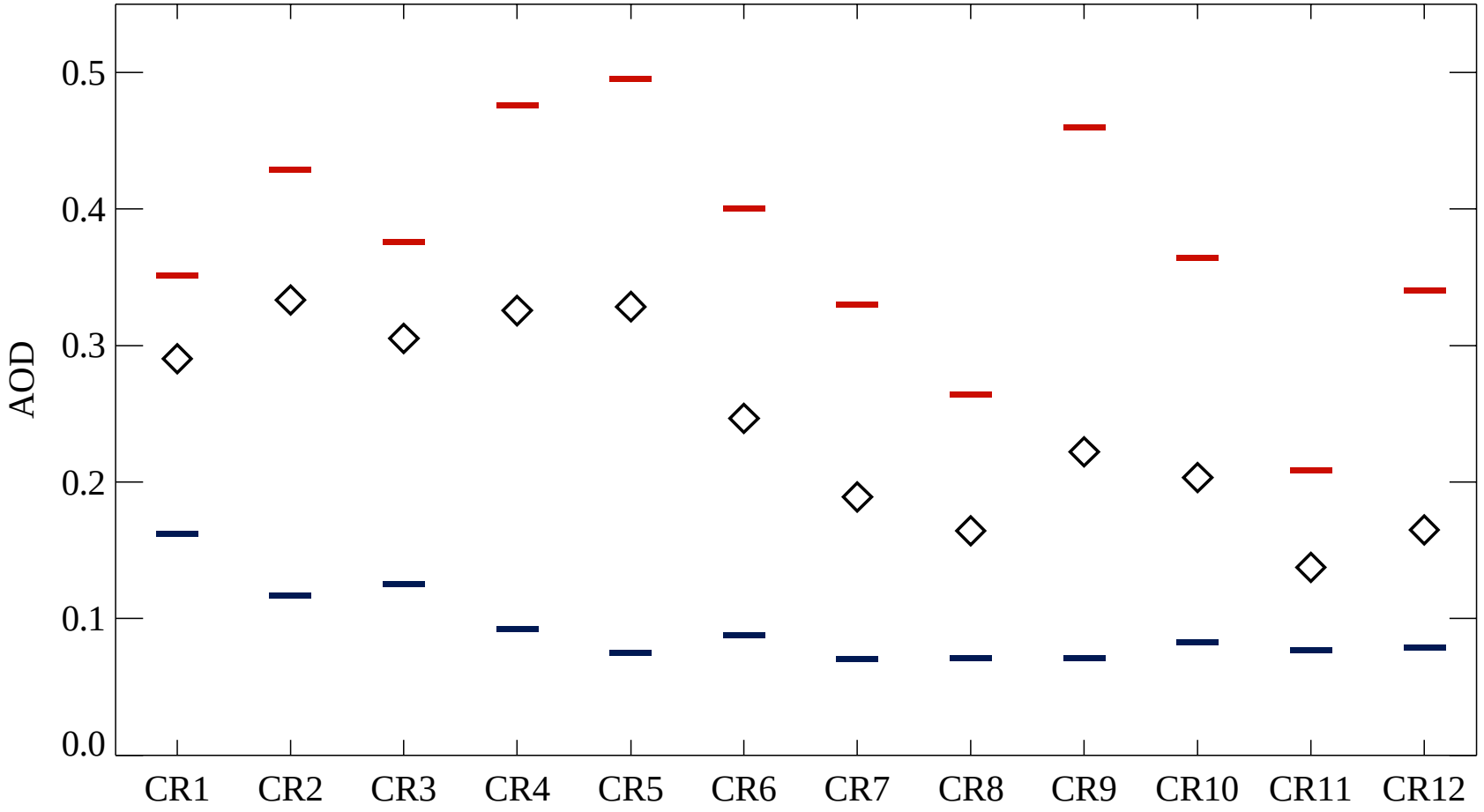


AOD

DJF



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.