



Insights gained by organizing MODIS joint
histograms into cloud regimes

Lazaros Oreopoulos (NASA-GSFC)

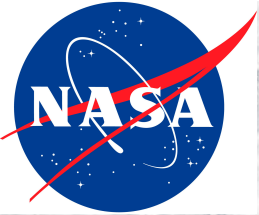
Nayeong Cho (USRA/NASA-GSFC)

Dongmin Lee (Morgan State/NASA-GSFC)

Daeho Jin (USRA/NASA-GSFC)

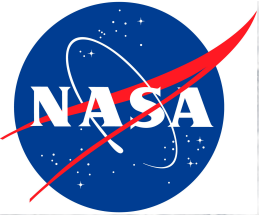
Tianle Yuan (JCET/NASA-GSFC)

Acknowledgements: Science of Terra-Aqua program



Motivation

- Study processes by “cloud type”
- “Cloud type” from MODIS is quite ambiguous
- Water phase or CTH (low-middle-high) perhaps too simplistic for distinguishing between cloud types
- In areas $\sim(100\text{km})^2$ multiple cloud types may exist
- Therefore it may make more sense to talk about cloud “mixtures”, the most dominant of which are “regimes”
- Regimes obtained by clustering analysis applied to cloud property co-variations



MODIS cloud regime (CR) analysis so far

- How CRs look from active sensors (CloudSat/CALIPSO)
- CR Thermodynamic environment from AIRS
- Breakdown by CR of precipitation and radiation budget
- Aerosol effects on clouds and precipitation by CR
- Horizontal cloud inhomogeneity by CR
- How CRs will change with C6

 **AGU** PUBLICATIONS

JGR

Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE

10.1002/2013JD021409

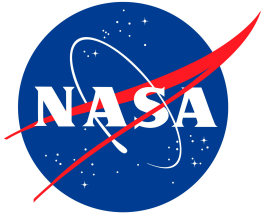
Key Points:

- Cloud systems observed by passive sensors can be decomposed into cloud regimes
- The regimes have distinct structures

An examination of the nature of global MODIS cloud regimes

Lazaros Oreopoulos¹, Nayeong Cho^{1,2}, Dongmin Lee^{1,3}, Seiji Kato⁴, and George J. Huffman¹

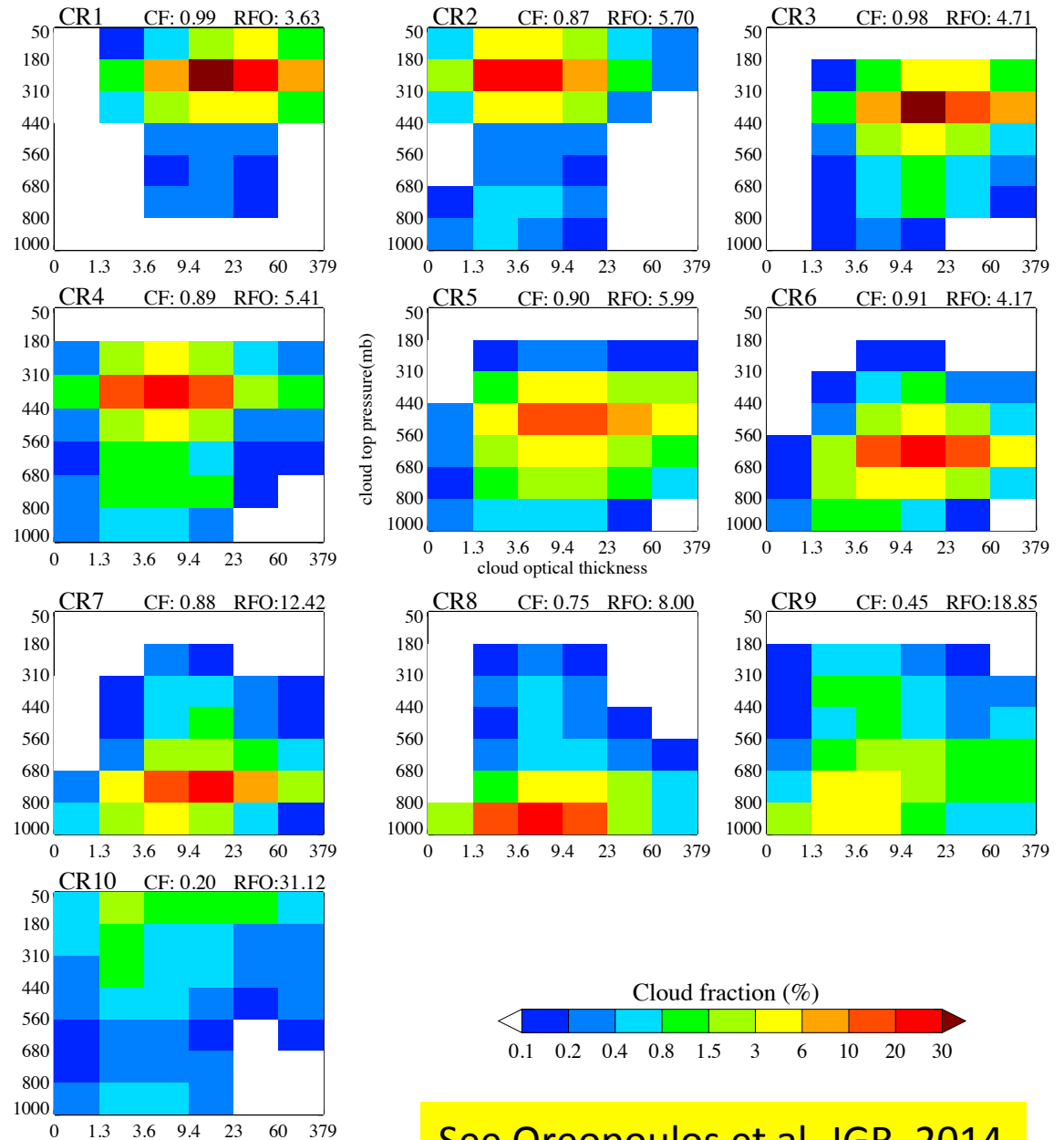
¹NASA-GSFC, Earth Science Division, Greenbelt, Maryland, USA, ²USRA, Columbia, Maryland, USA, ³GESTAR, Morgan State University, Baltimore, Maryland, USA, ⁴NASA-LARC, Climate Science Branch, Hampton, Virginia, USA



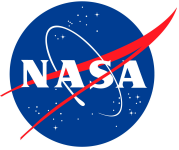
MODIS dynamical cloud regimes (CRs)

Systematic patterns in co-variations of cloud extinction and vertical location according to MODIS

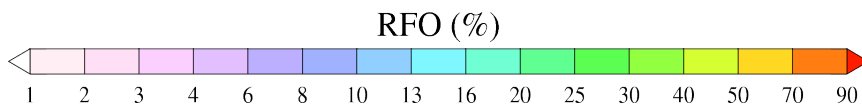
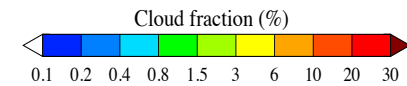
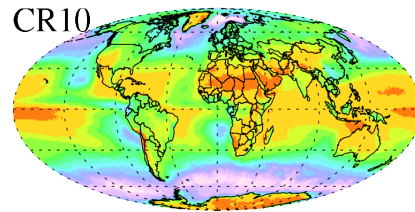
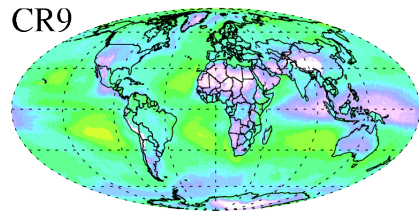
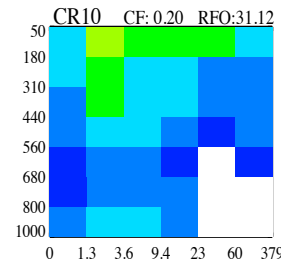
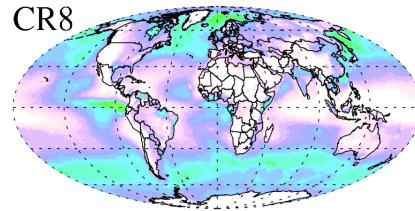
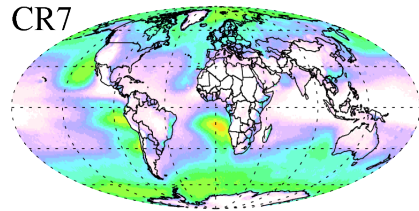
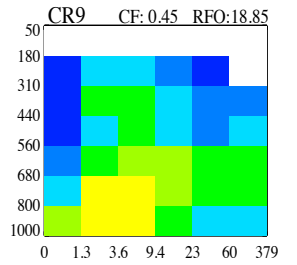
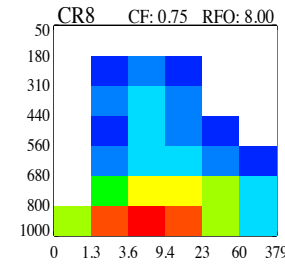
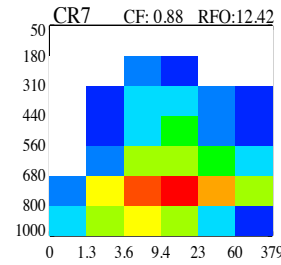
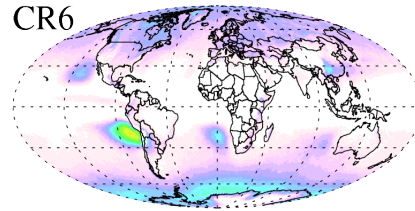
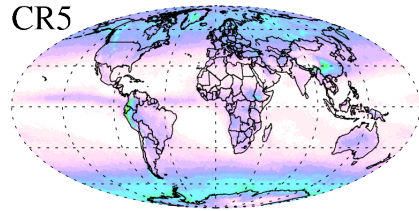
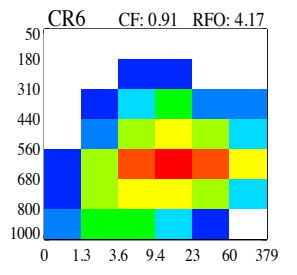
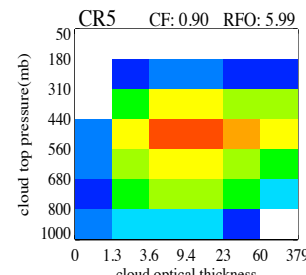
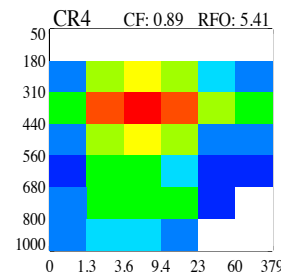
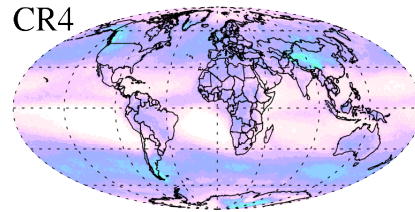
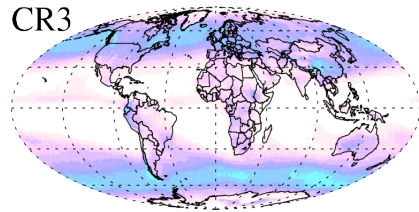
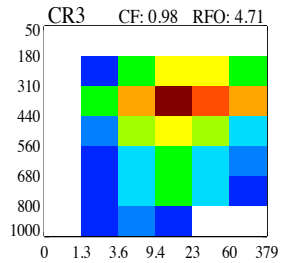
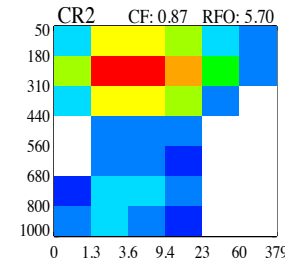
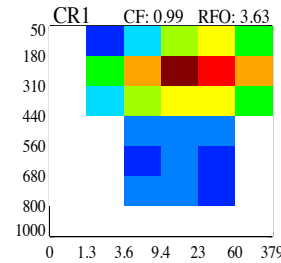
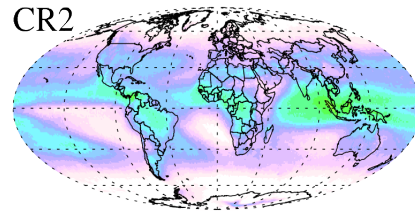
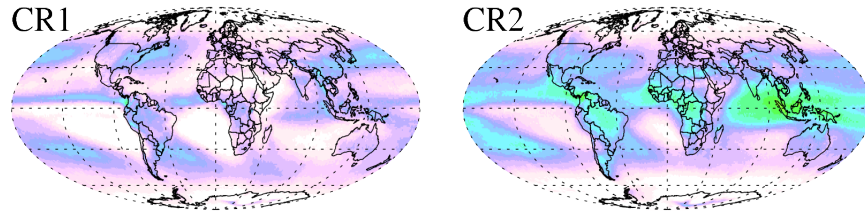
L-3, daily data, Terra and Aqua

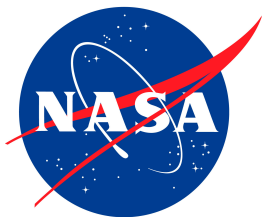


See Oreopoulos et al. JGR, 2014

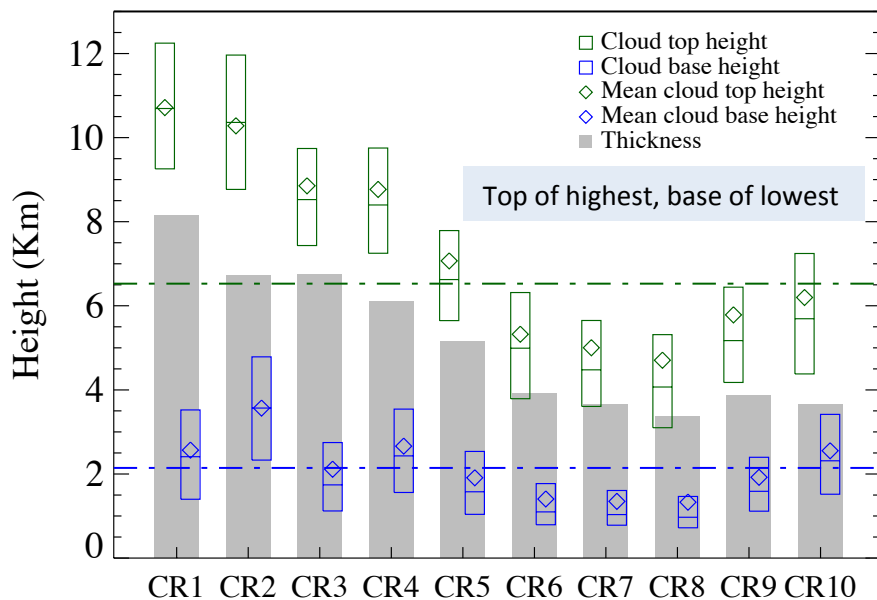
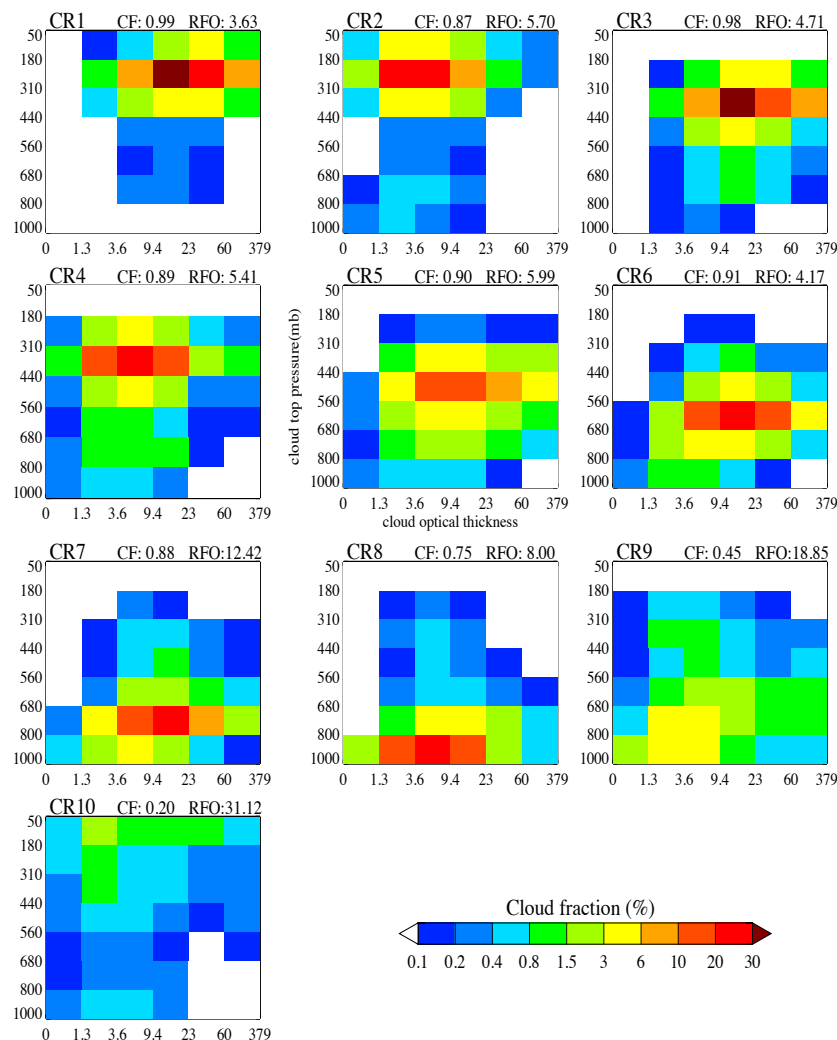
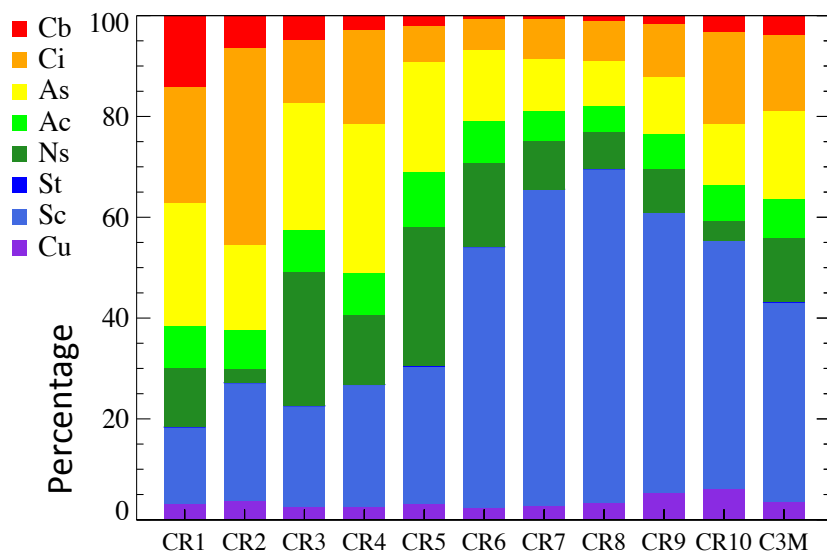


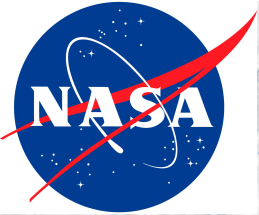
Where the dynamical CRs occur





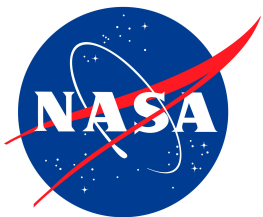
Breakdown of Aqua dynamical CRs by CloudSat cloud type



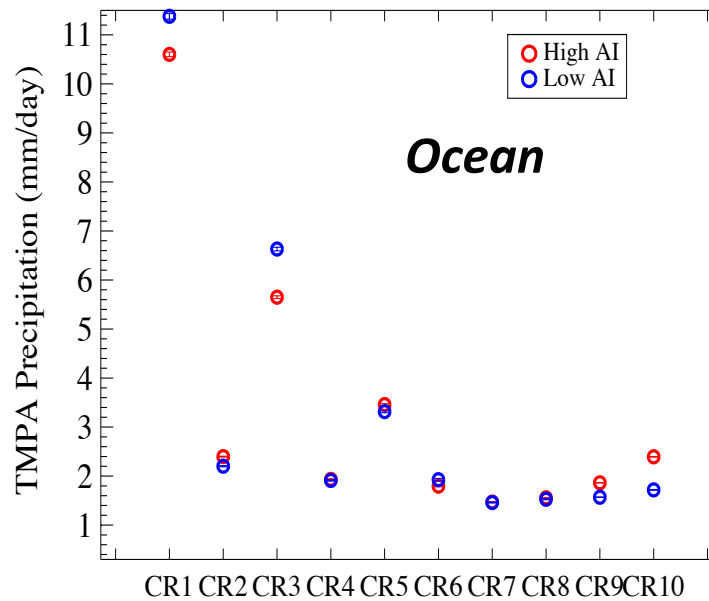
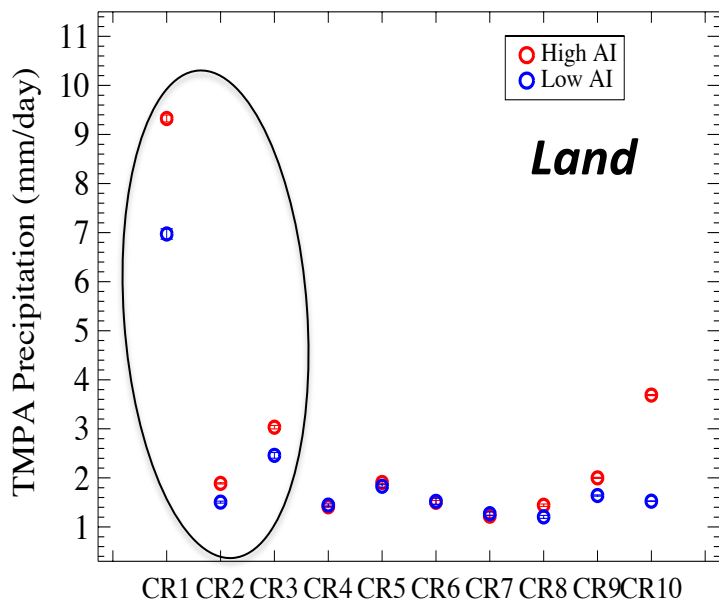


Aerosol effects on clouds and precipitation

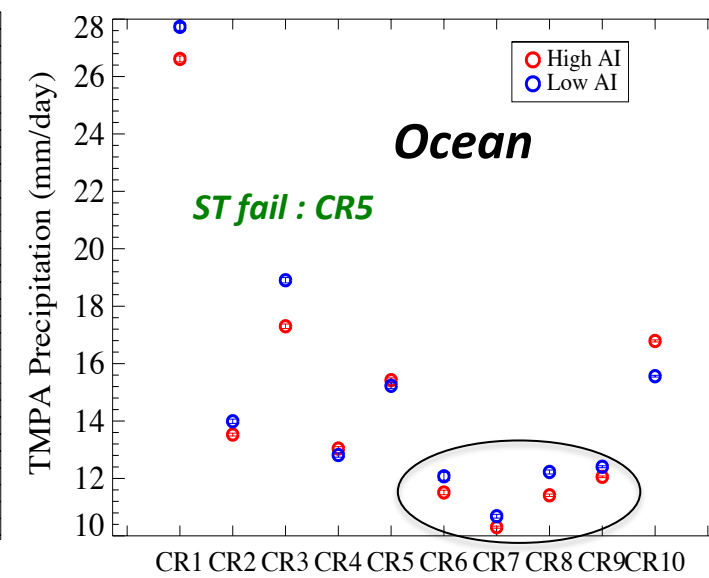
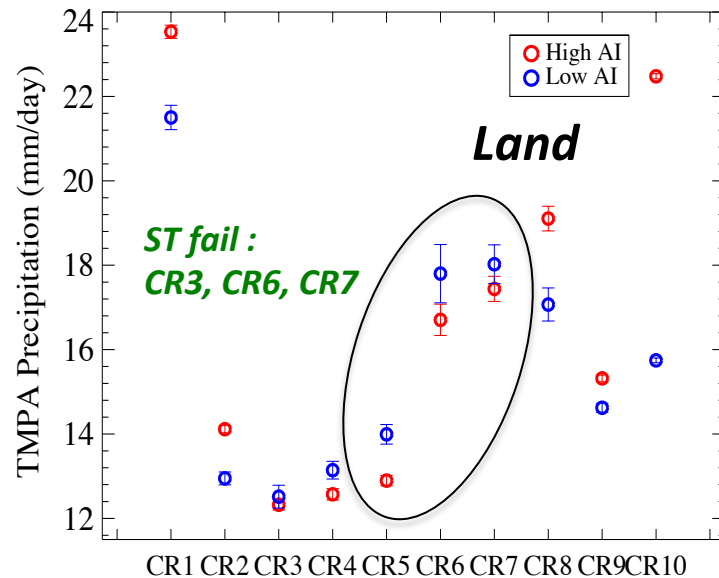
- Level-3 C5.1 MODIS Aqua and Terra daily data
- TMPA surface precip 3-h 0.25° data; match with MODIS
- For each MODIS 1° gridcell with an AOD (from either Terra or Aqua) we calculate the AI (=AODxAngstrom); AI relates to aerosol column number. We calculate gridcell seasonal AI distributions for each gridcell and perform composite by CR and AI percentile.
- We often focus on the upper (3Q, “high” aerosol) and lower (1Q, “low” aerosol) quartile and perform statistical significance tests
- Land/ocean separation helpful
- High latitudes (>50°) are excluded from the analysis (no precip available from TMPA)



3Q vs 1Q precipitation (50S-50N)



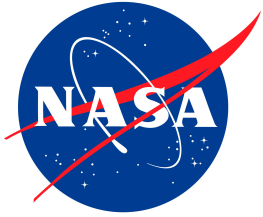
Zero precipitation included



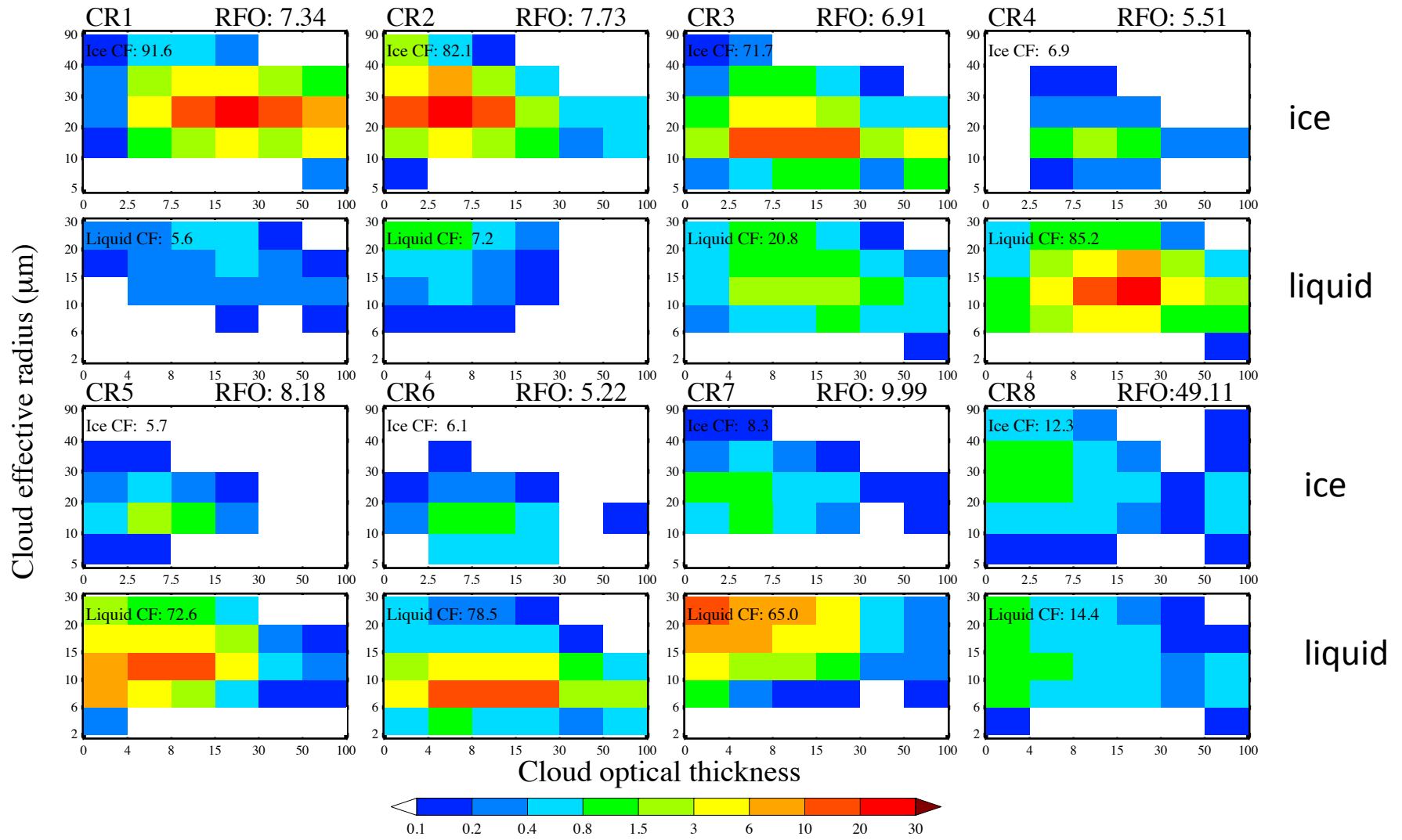
Zero precipitation excluded

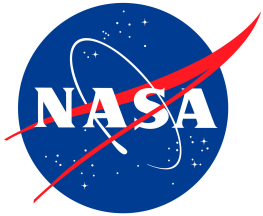
An aerial photograph of a massive glacier system, likely in Greenland, showing complex flow patterns and numerous ice streams. A white vector field is overlaid on the image, representing the direction and relative speed of ice flow. The text "Microphysical regimes" is centered over the image in a bold, blue font.

Microphysical regimes

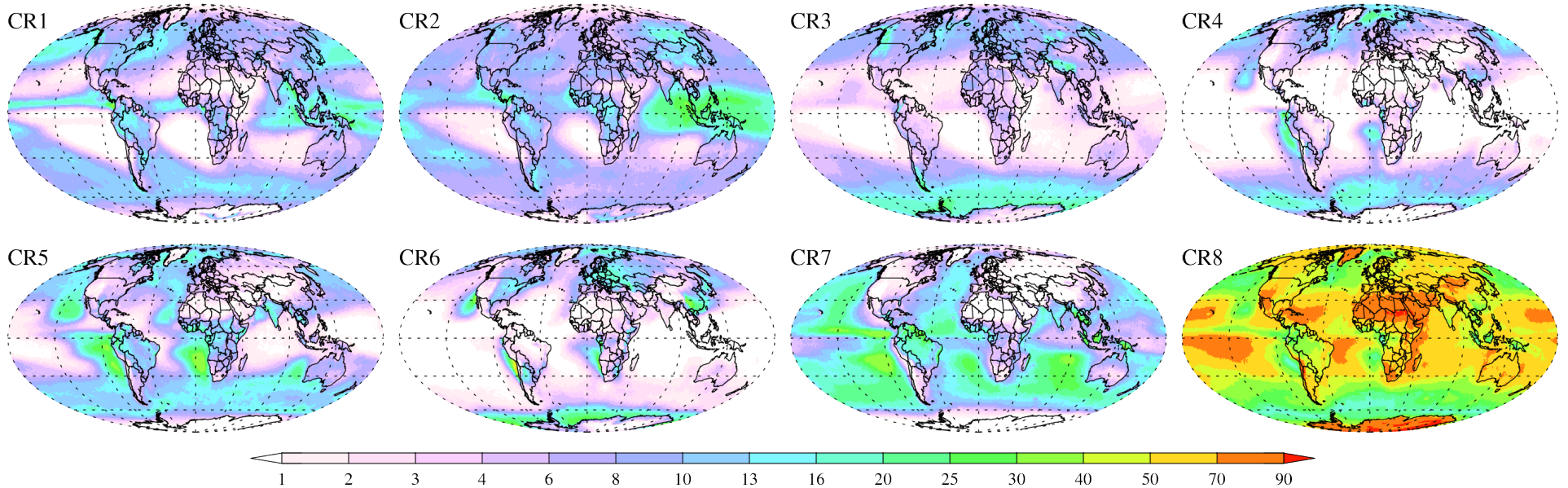
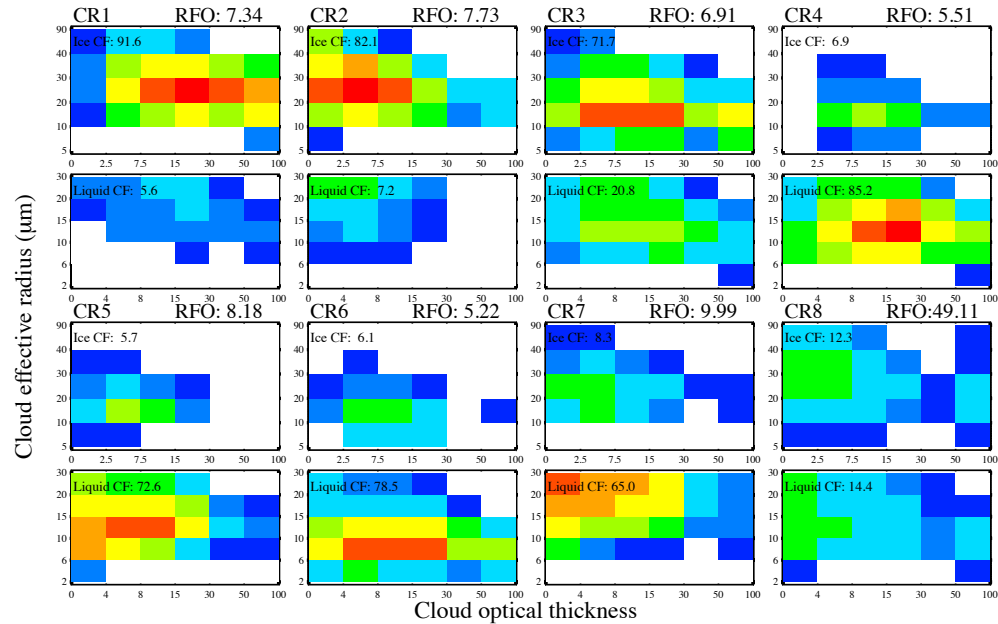


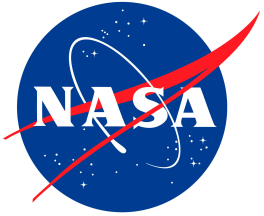
MODIS microphysical regimes (C5.1)





C5.1 MODIS microphysical regimes

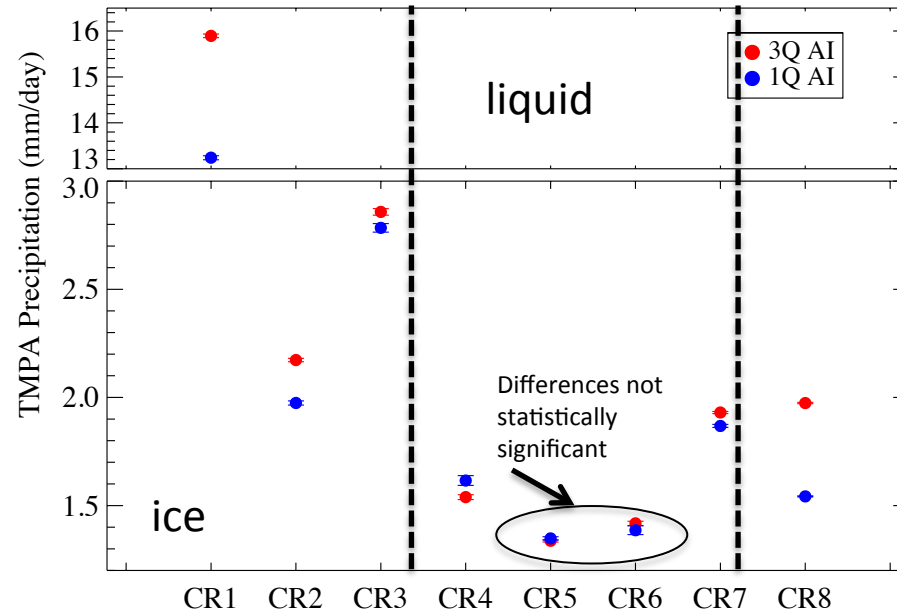




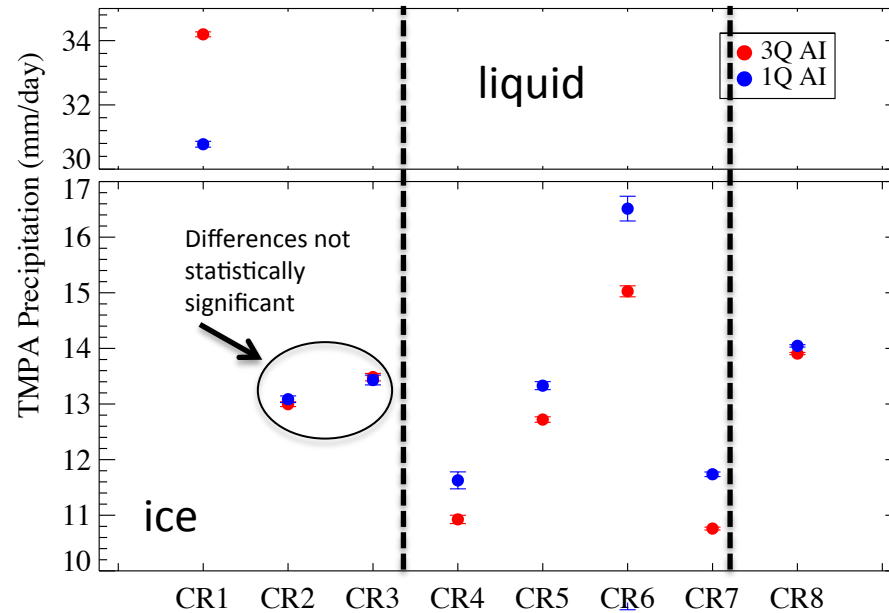
3Q vs 1Q precipitation (50S-50N)

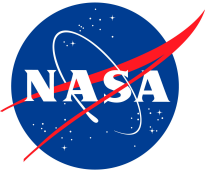
Zero precipitation included

3Q=high aerosol
1Q=low aerosol



Zero precipitation excluded





Summary

From low to high AI

DCR=dynamical regimes; MCR=microphysical regimes

	DCR_{ice} Land/Ocean		DCR_{liq} Land/Ocean		DCR_{10}	MCR_{ice}	MCR_{liq}	MCR_8
Prcp	↑↑	↓↓	-		↑↑	↑↑	-	↑↑
CF	-		↑↑		↑↑	-	↑↑	↑↑
CTH	↑↑		↑↑	-	↑↑	↑↑	-	↑↑
Tau	↑↑	↓↓	↑↑		↑↑	↓↓	↑↑	↑↑
Re	↓↓	-	↓↓		↑↑	-	-	-
PrcpNZ	↑↑	↓↓	-	↓↓	↑↑	↑↑	↓↓	-

red arrow: consistent with invigoration; blue arrow: consistent with 1st and 2nd indirect effect

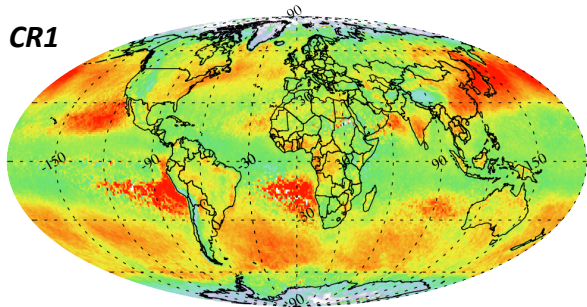
A satellite image of Earth showing cloud cover over the Atlantic Ocean and parts of Europe and Africa. The clouds are white and wispy, with some darker areas indicating lower cloud density. The text "Cloud horizontal inhomogeneity" is overlaid in blue.

Cloud horizontal inhomogeneity

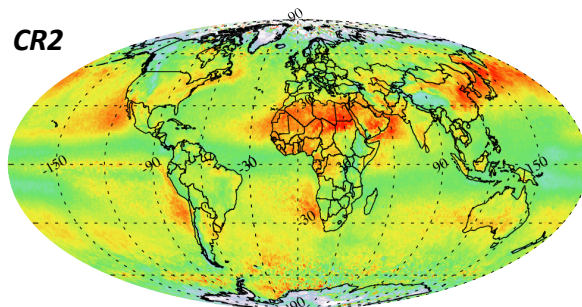
$$\chi = e^{\frac{\overline{\ln \tau}}{\tau}}$$

Global mean values for inhomogeneity parameter

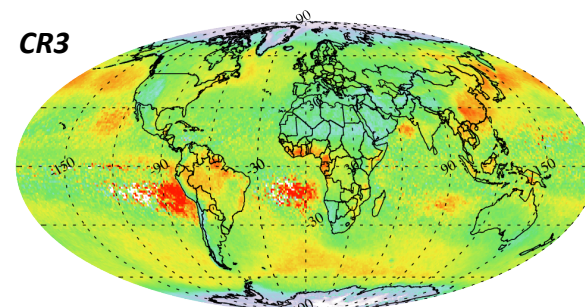
CR1



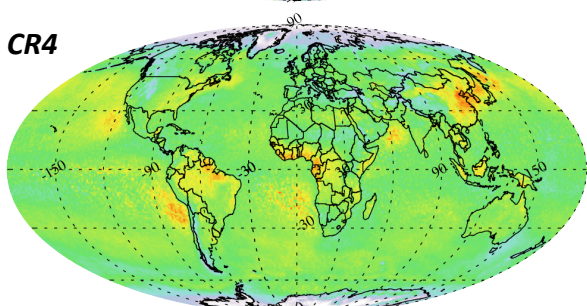
CR2



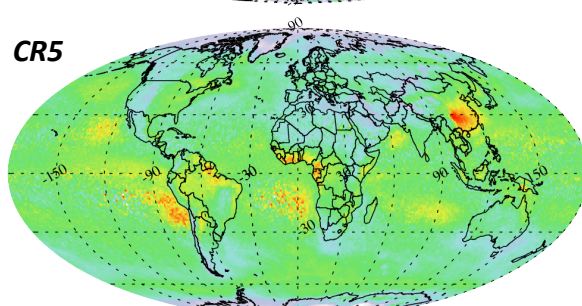
CR3



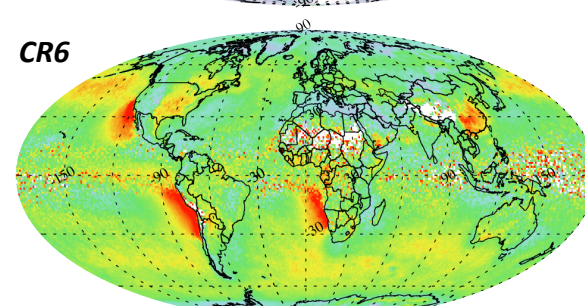
CR4



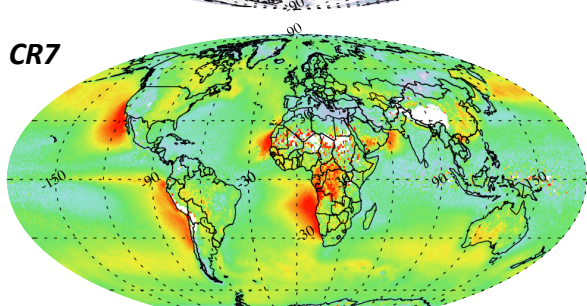
CR5



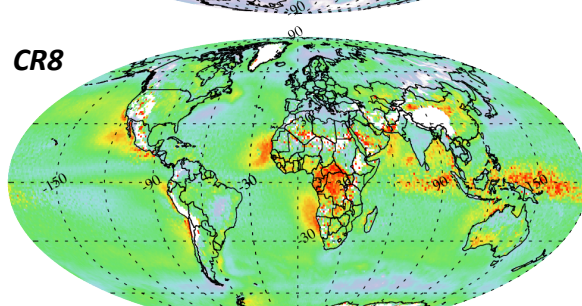
CR6



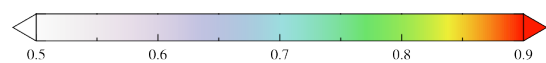
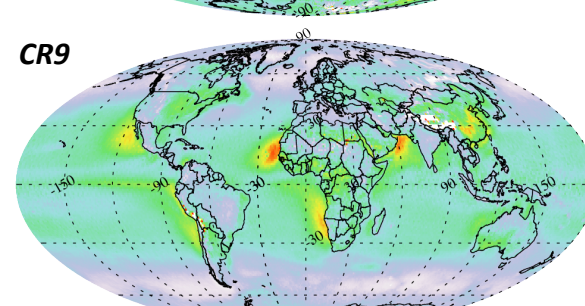
CR7



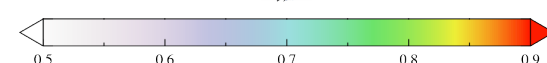
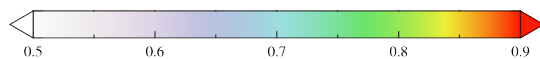
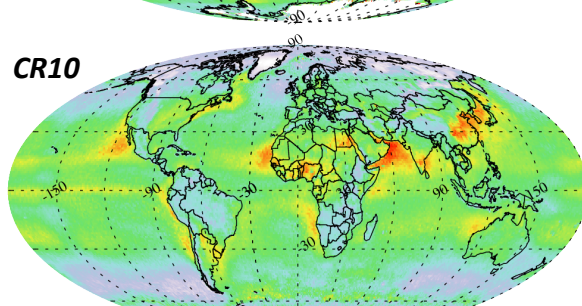
CR8



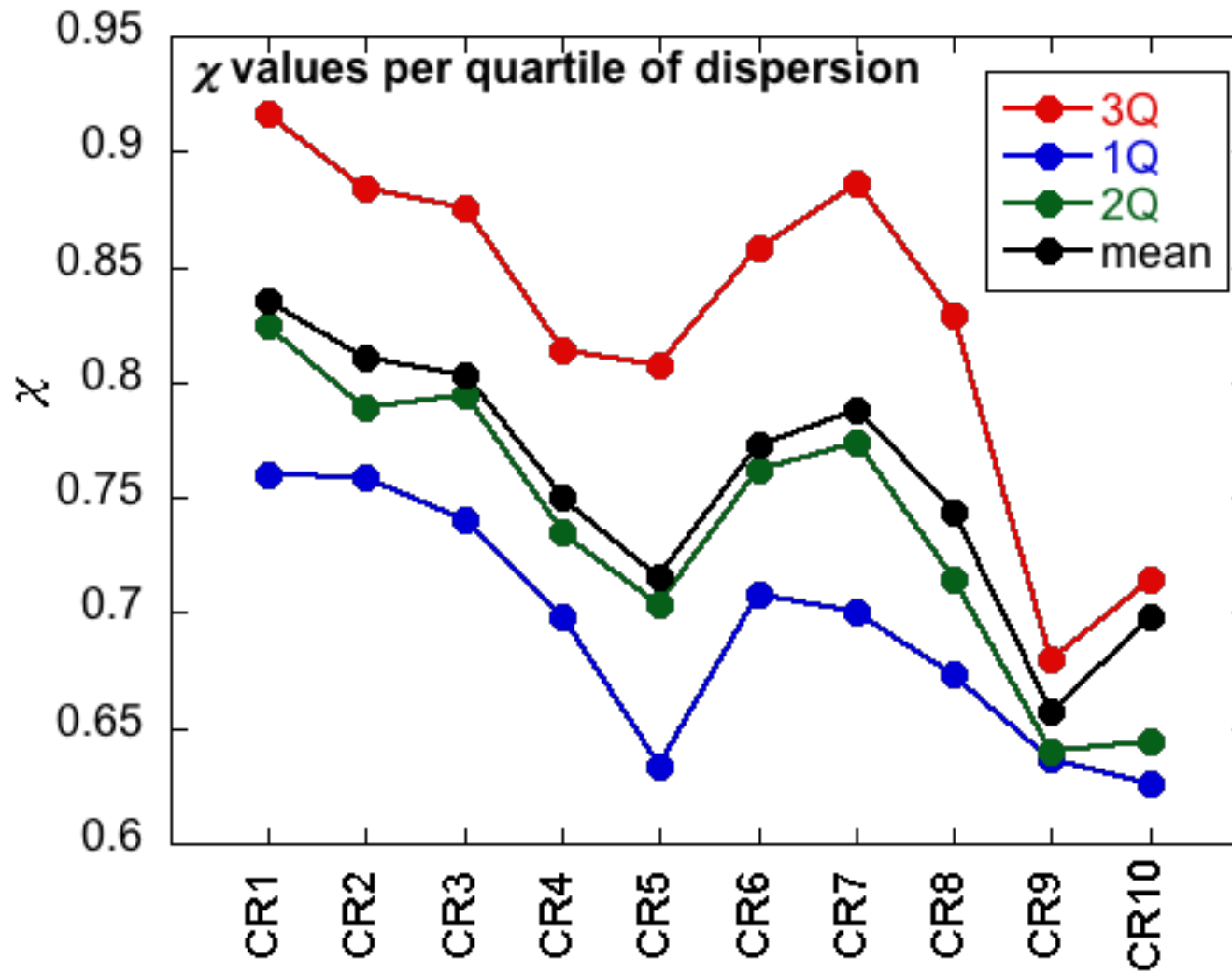
CR9



CR10



Inhomogeneity by and within CRs

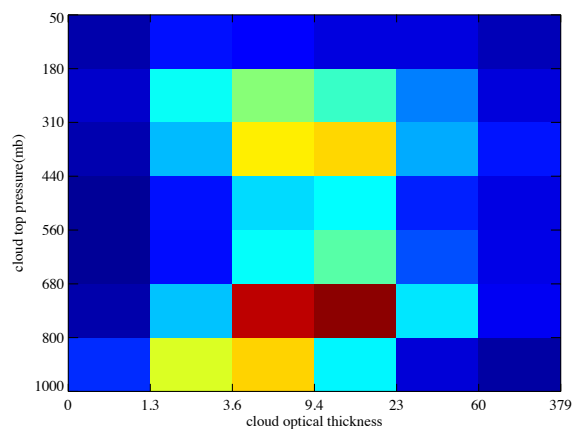


An aerial photograph of a massive glacier system, likely in the Himalayas, showing intricate patterns of ice flow and meltwater channels. The glacier is a mix of white and light blue, with darker blue lines indicating meltwater streams. The surrounding terrain is rugged and mountainous. In the center, the text "Collection 6 impacts" is overlaid in a bold, blue, sans-serif font.

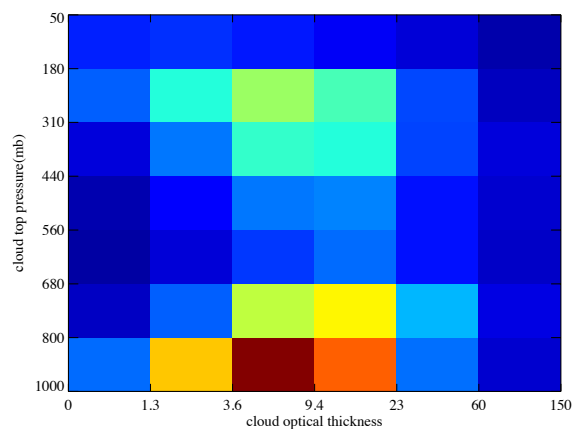
Collection 6 impacts

Dynamical CRs will change with Collection 6

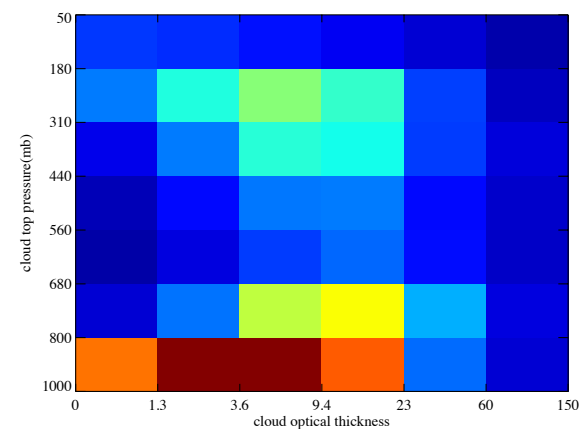
C5.1



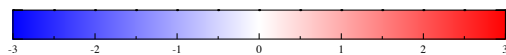
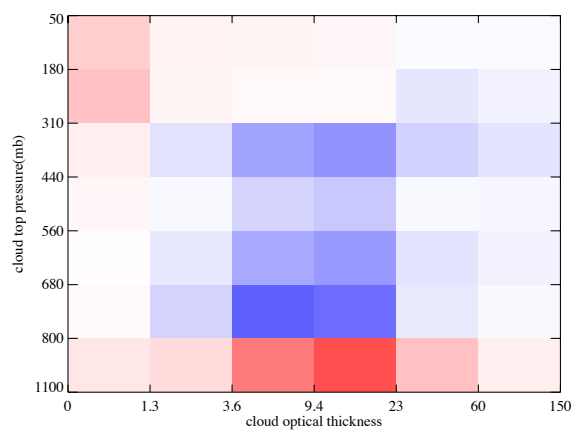
C6



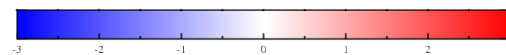
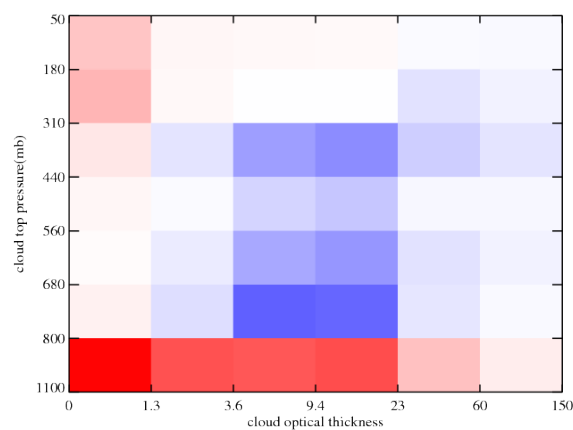
C6 with PCL



C6 – C5.1

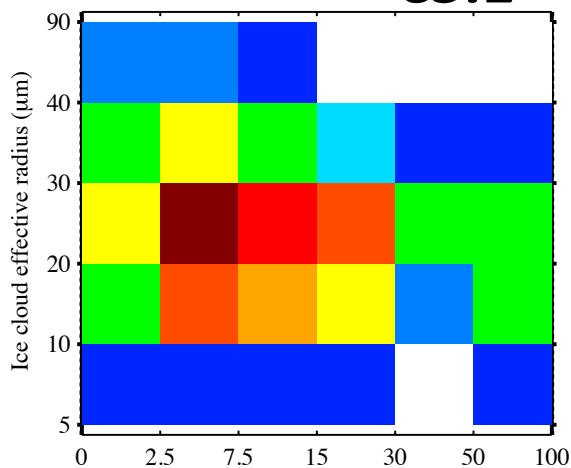


C6 with PCL – C5.1

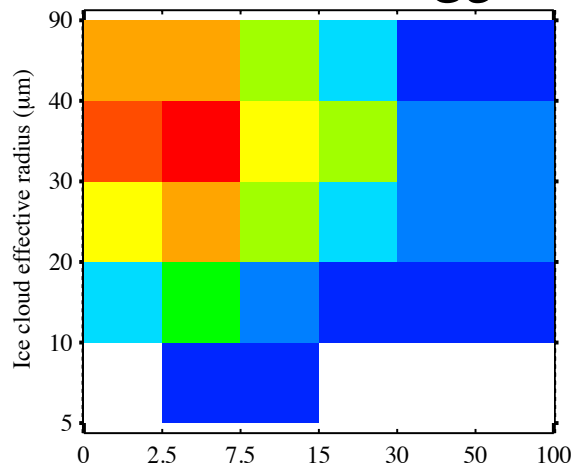


Ice microCRs will change with Collection 6

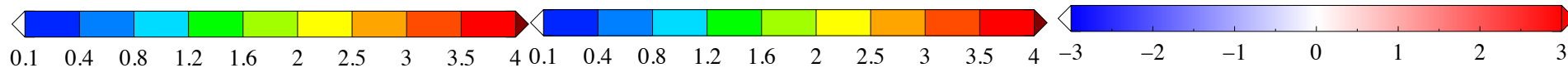
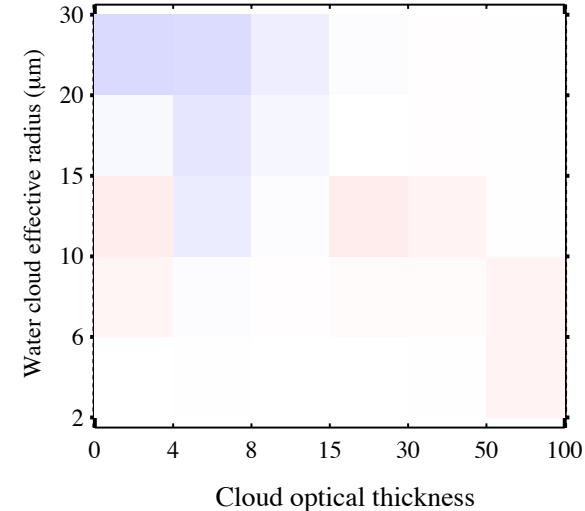
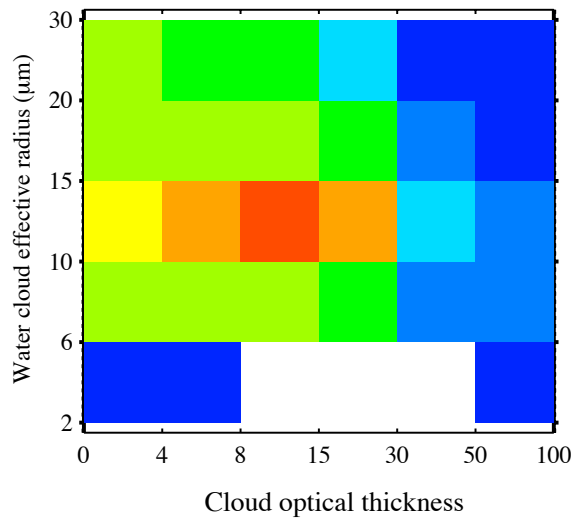
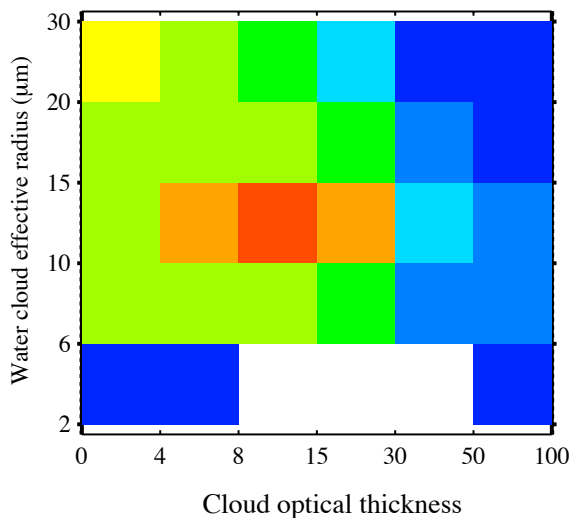
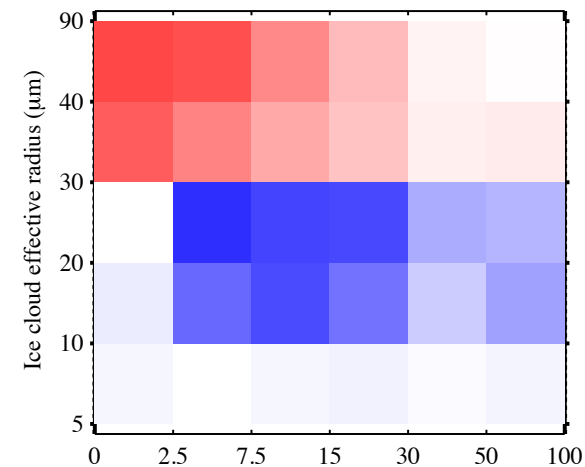
C5.1



C6

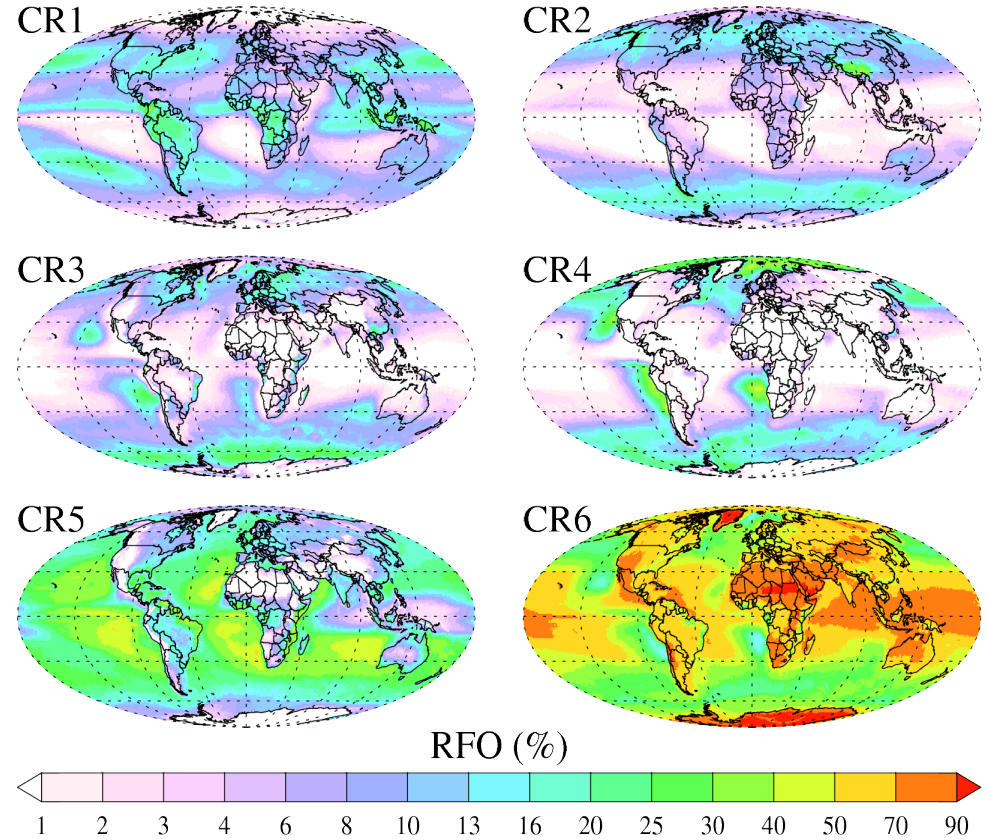
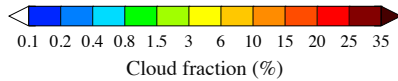
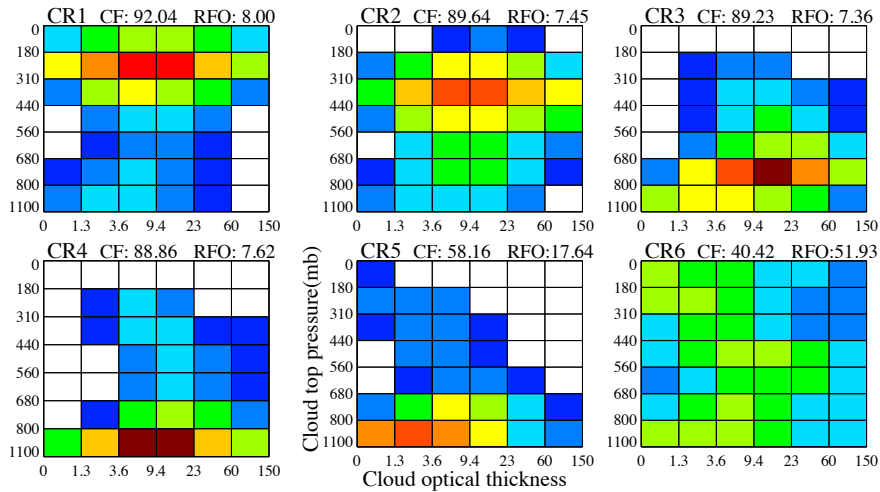


C6 - C5.1

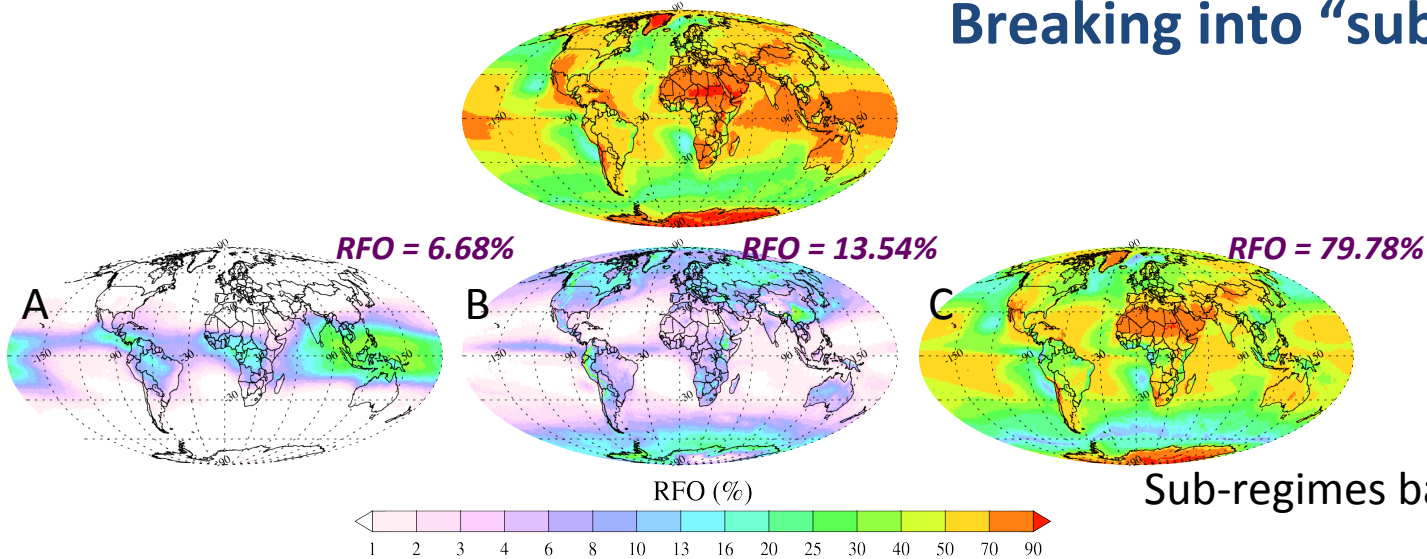


Preview of Collection 6 dynamical CRs

C6 PCL



Breaking into "sub-regimes"



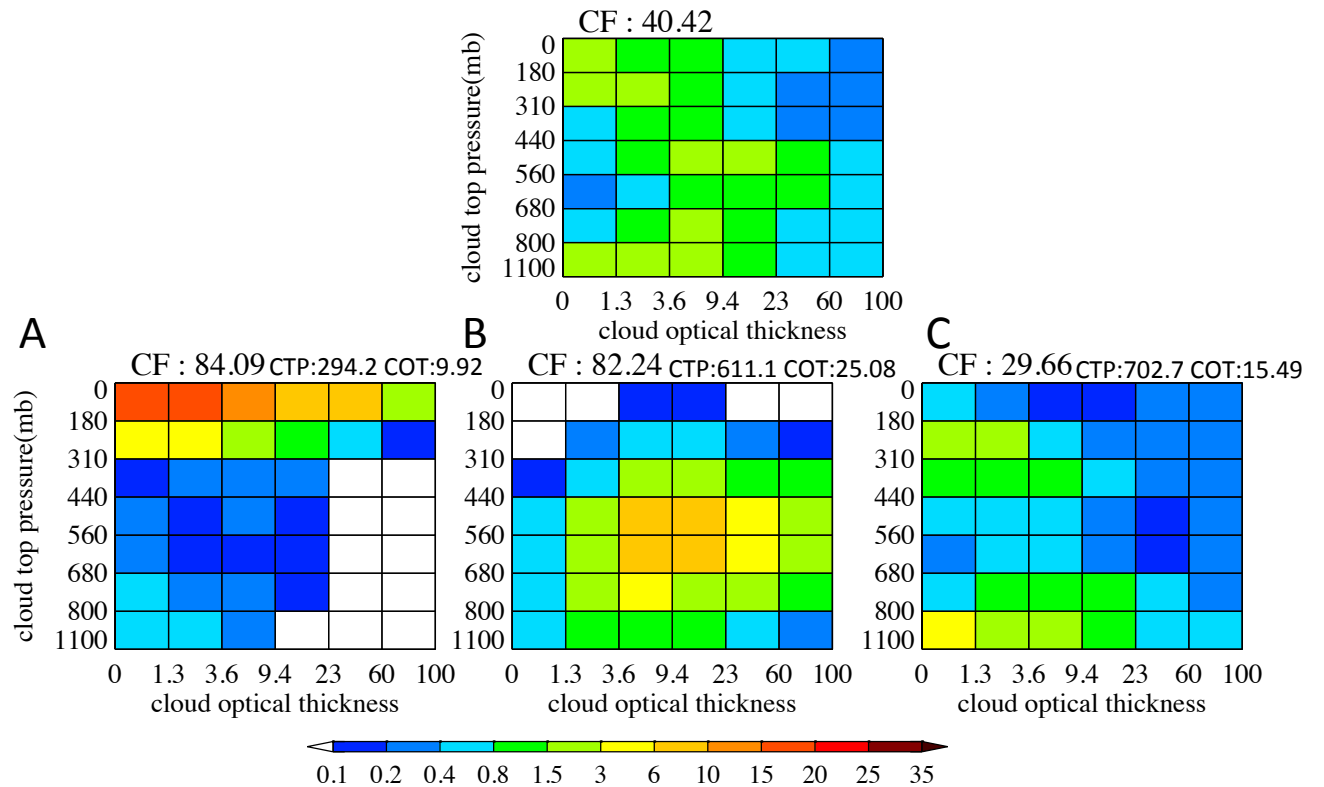
Map correlation coefficient

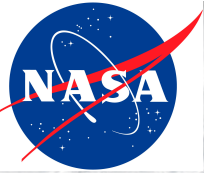
A-B : -0.37
A-C : 0.06
B-C : -0.09

Sub-regimes based on re-clustering
Repeatability = 18/20

Regime correlation coefficient

A-B : -0.32
A-C : -0.14
B-C : -0.14



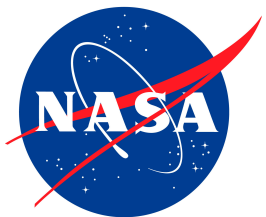


Take home messages

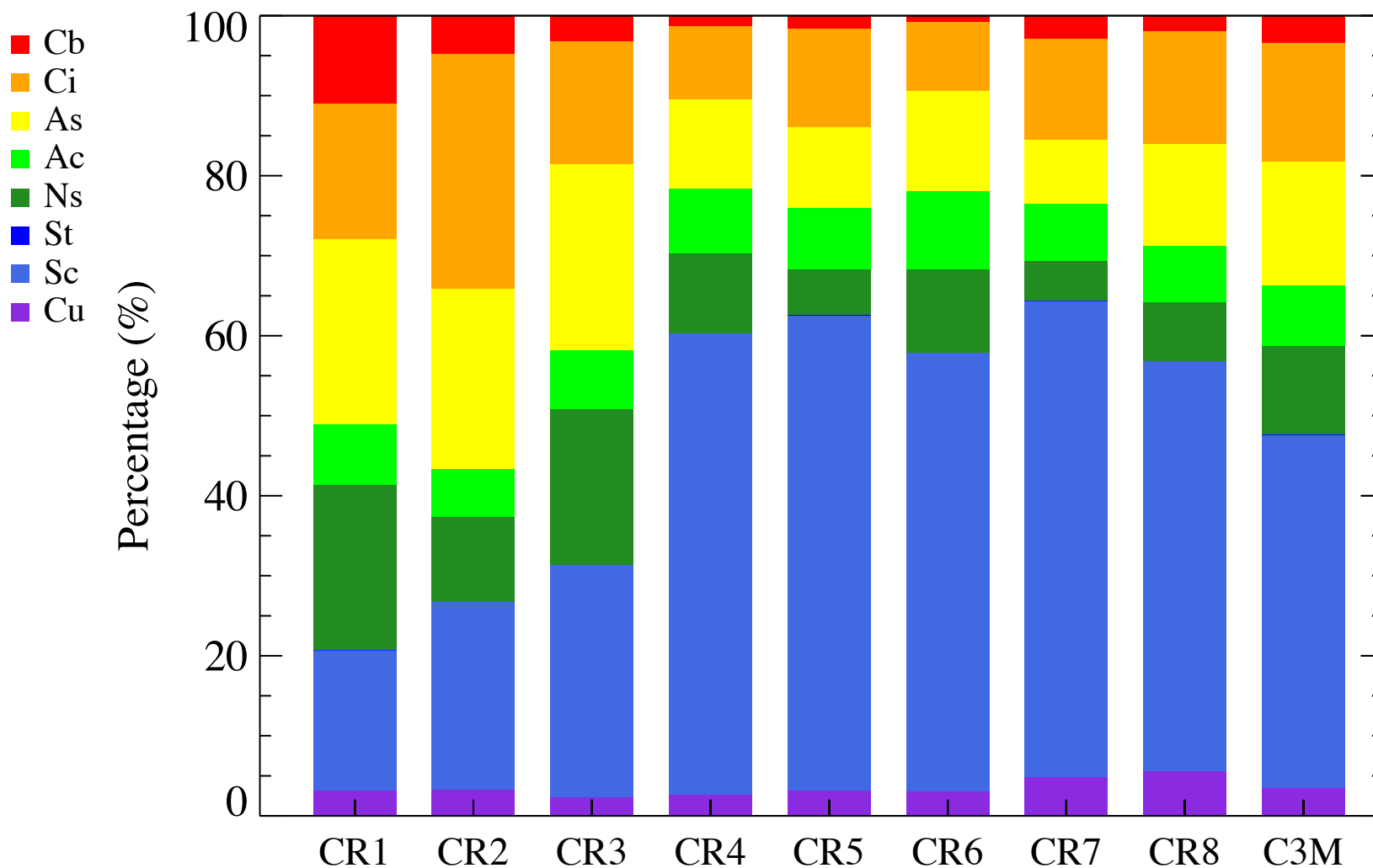
- A regime-based approach adds insight to many studies involving clouds
- Cloud regimes can be defined to be more closely associated with either dynamics or microphysics
- With MODIS simulator implemented in GCMs, a CR-based model validation becomes possible (work underway with ISCCP CRs and CMIP5 data)
- Robustness of CRs is important issue. C5.1 to C6 transition is expected to have impact

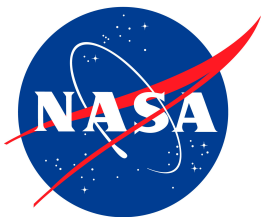
An aerial photograph of a massive glacier system, likely in the Himalayas or Andes. The glacier is a complex network of white and light blue ice, with numerous meltwater channels and streams cutting through it. The surrounding terrain is rugged and mountainous, with some green vegetation visible at the bottom right. The text "Additional slides" is overlaid in the center in a bold, blue font.

Additional slides

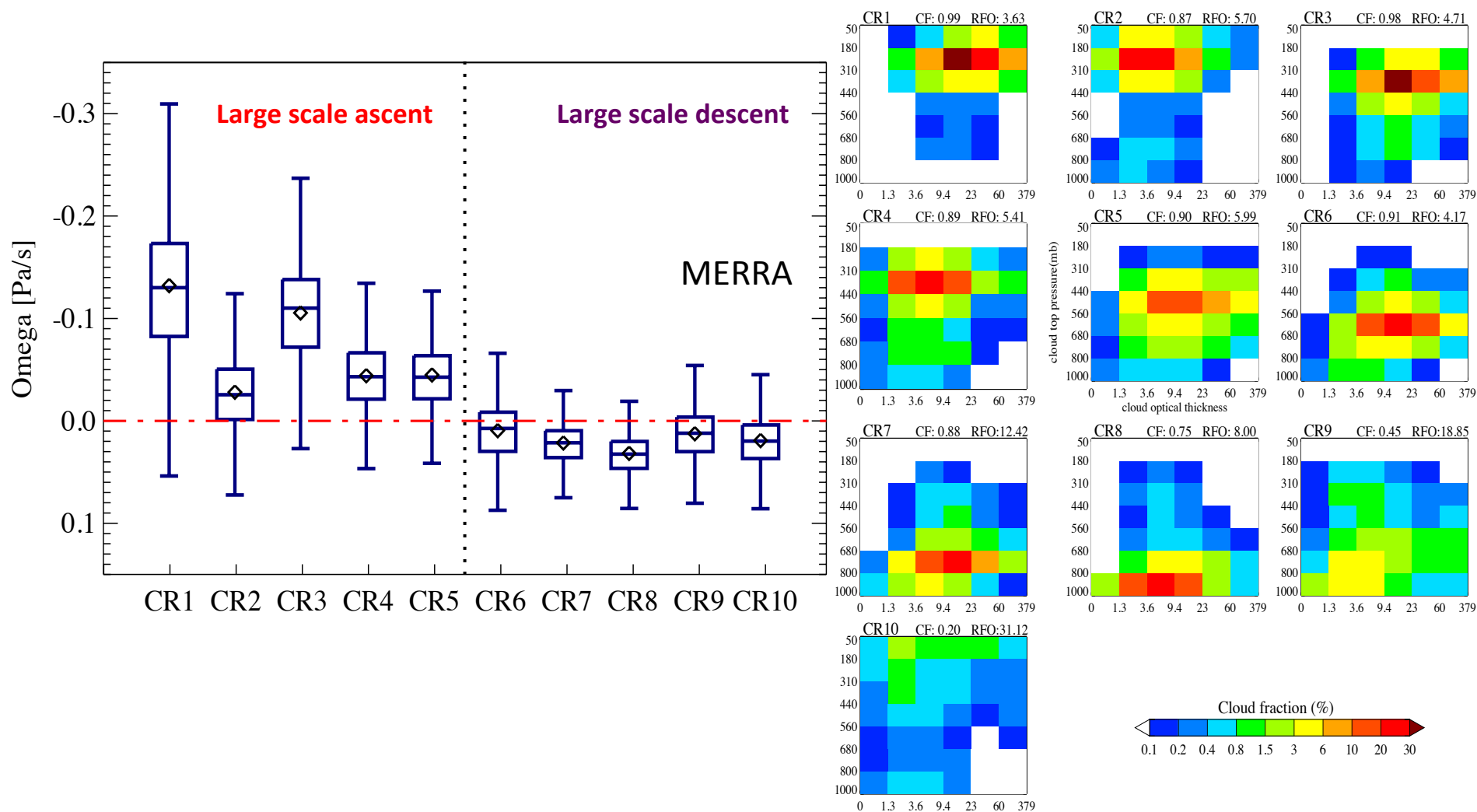


Breakdown of Aqua microCRs by CloudSat cloud type

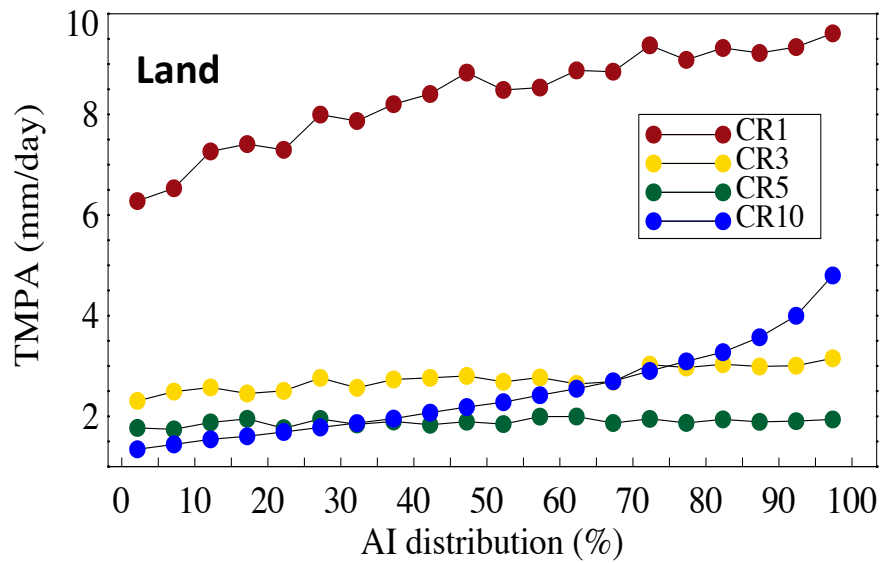
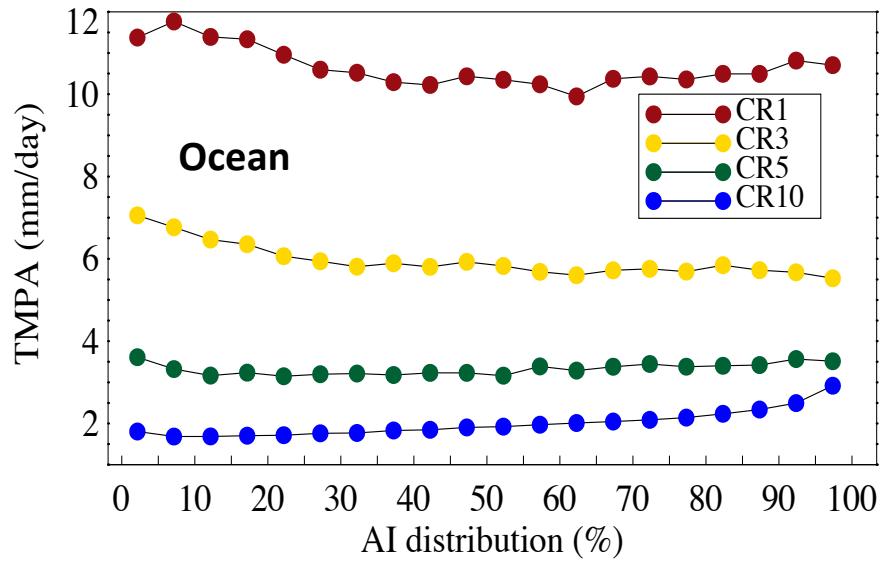




Why dynamical



Dynamical regimes



Microphysical regimes

