Employing MODIS cloud regimes to find signals of aerosol-cloud-precipitation interactions

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OVERVIEW

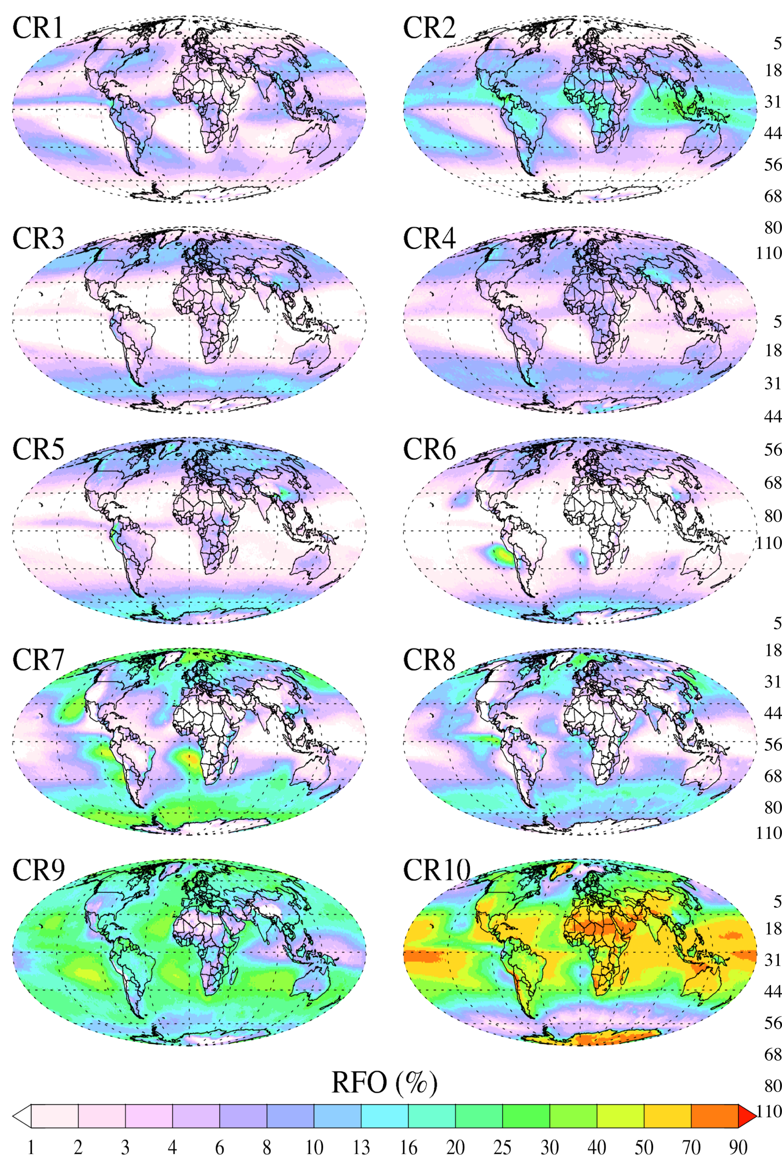
- A Cloud Regime (CR) approach is used to study aerosol-cloud-precipitation relationships.
- 10 years of MODIS Terra-Aqua C5.1 daily joint (2D) histograms of Cloud Top pressure (CTP) vs Cloud Optical Thickness (COT) and Cloud Effective Radius (CER, liquid and ice phase) vs COT are used to derived global CRs using clustering analysis.
- We composite CR *properties*, namely COT, CTP, Cloud Fraction (CF), and CER, as well as TRMM *precipitation.*
- The *AI (= AOD x Ångström exponent)* parameter from MODIS, thought to correlate better with CCN than AOD, is used to examine relationships between aerosols and clouds.
- The seasonal AI distribution for each 1˚x1˚ gridcell is broken into vigintiles (5% increments). *High* and *low AI* are defined as the highest and lowest AI *quartile*, respectively.
- TRMM Multi satellite Precipitation Analysis TMPA-3B42 rainfall is composited for each CR, and separately for each AI vigintile.

MAIN FINDINGS

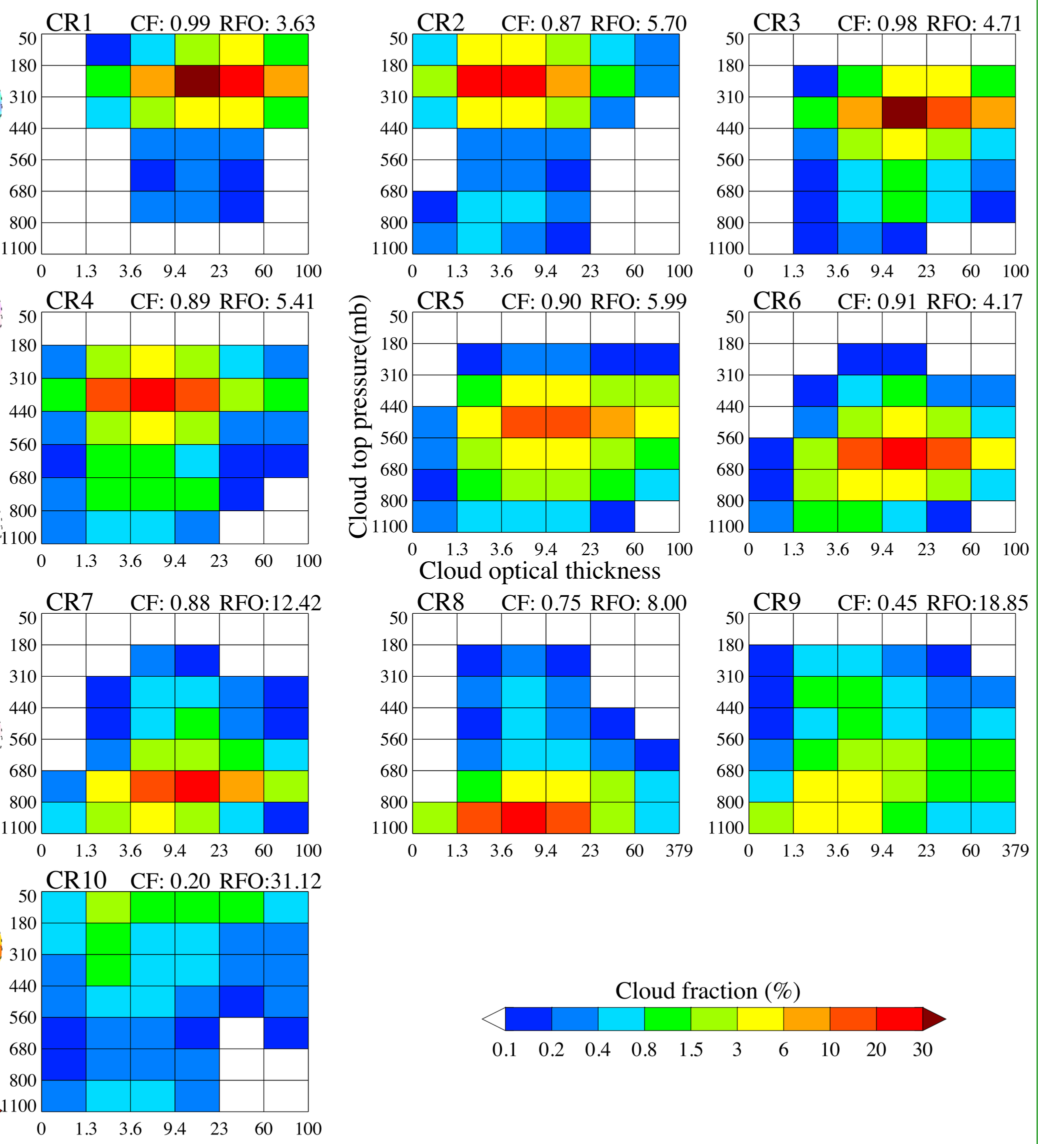
- We find that ice- and liquid-dominated regimes have different characteristics under high and low aerosol loadings using two different types of MODIS cloud regimes.
- There are clear signals of precipitation increase from low to high AI for ice-dominated CRs over land, which is consistent with the hypothesized aerosol-driven convective invigoration. 1st and 2nd aerosol indirect effect appear for liquid dominated CRs.
- We suggest that microCRs may be a better basis for studying cloud-aerosol interactions rather than dynamical CRs.

The MODIS cloud regimes

[Dynamical regimes]



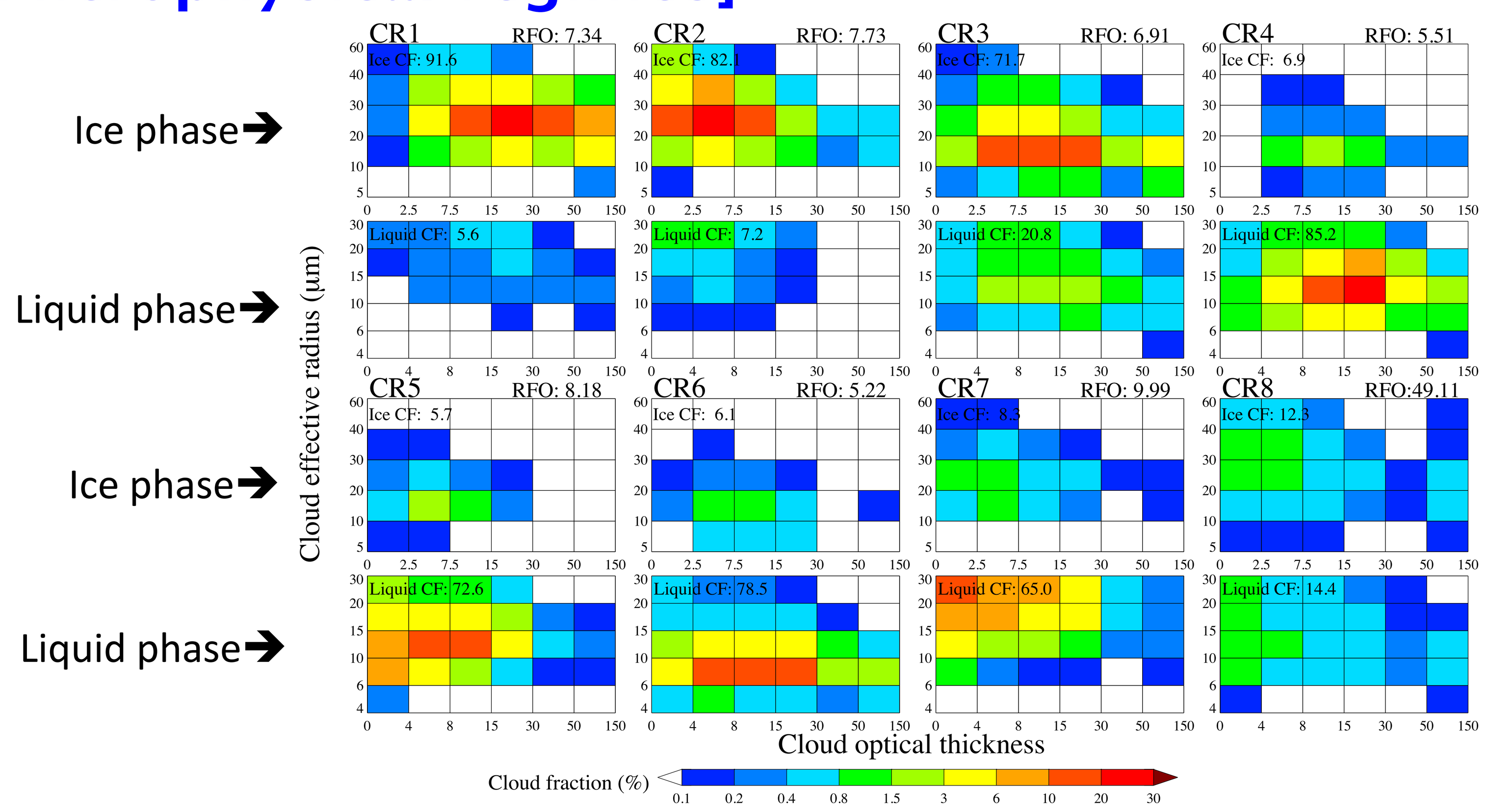
Geographical distribution of each regime's multi-annual relative frequency of occurrence (RFO).



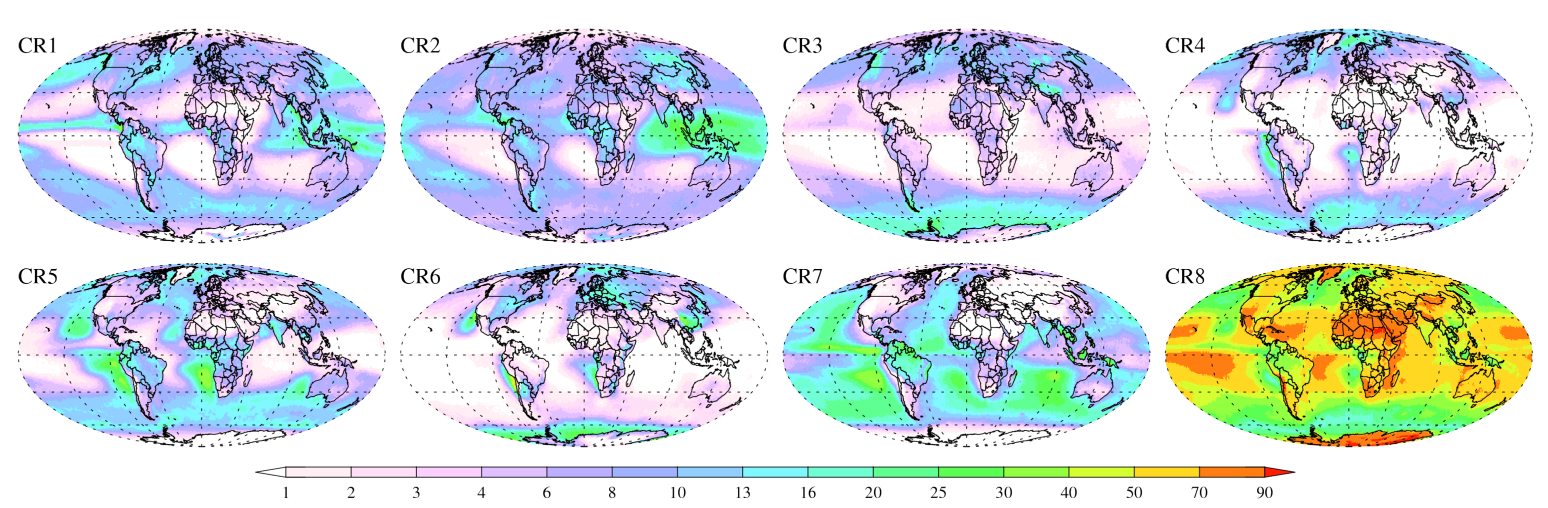
The MODIS dynamical CRs (cluster centroids) derived from clustering analysis. Each CR's global CF and RFO is provided.

Reference :Oreopoulos, et al (2014). An examination of the nature of global MODIS cloud regimes JGR, 119.doi:10.1002/2013JD021409

[Microphysical regimes]

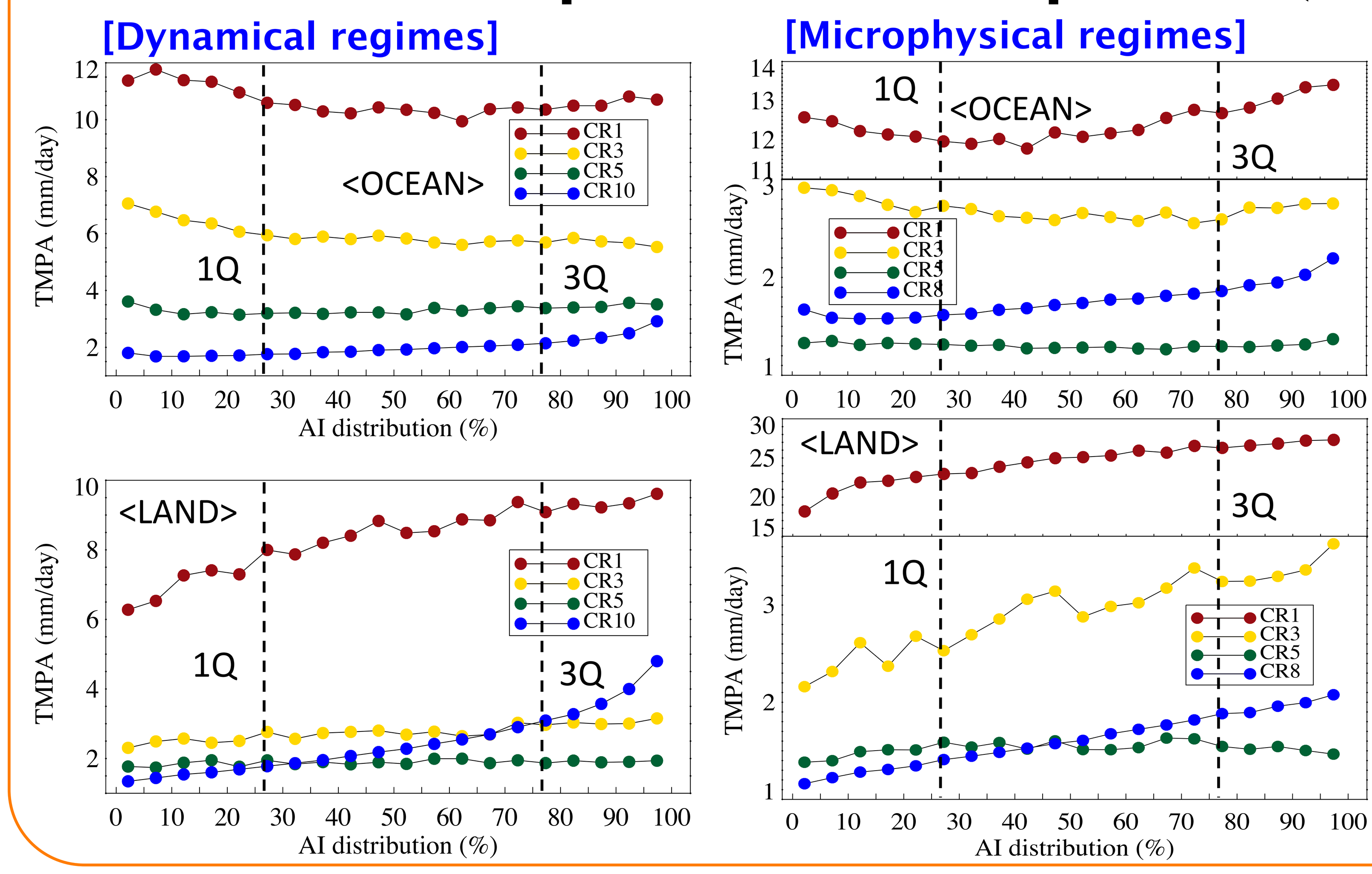


The MODIS microphysical CRs (cluster centroids) derived from clustering analysis. Each regime's global CF and RFO is provided.



Geographical distribution of each regime's multi-annual RFO.

Precipitation vs. AI per CR (50˚S to 50˚N)



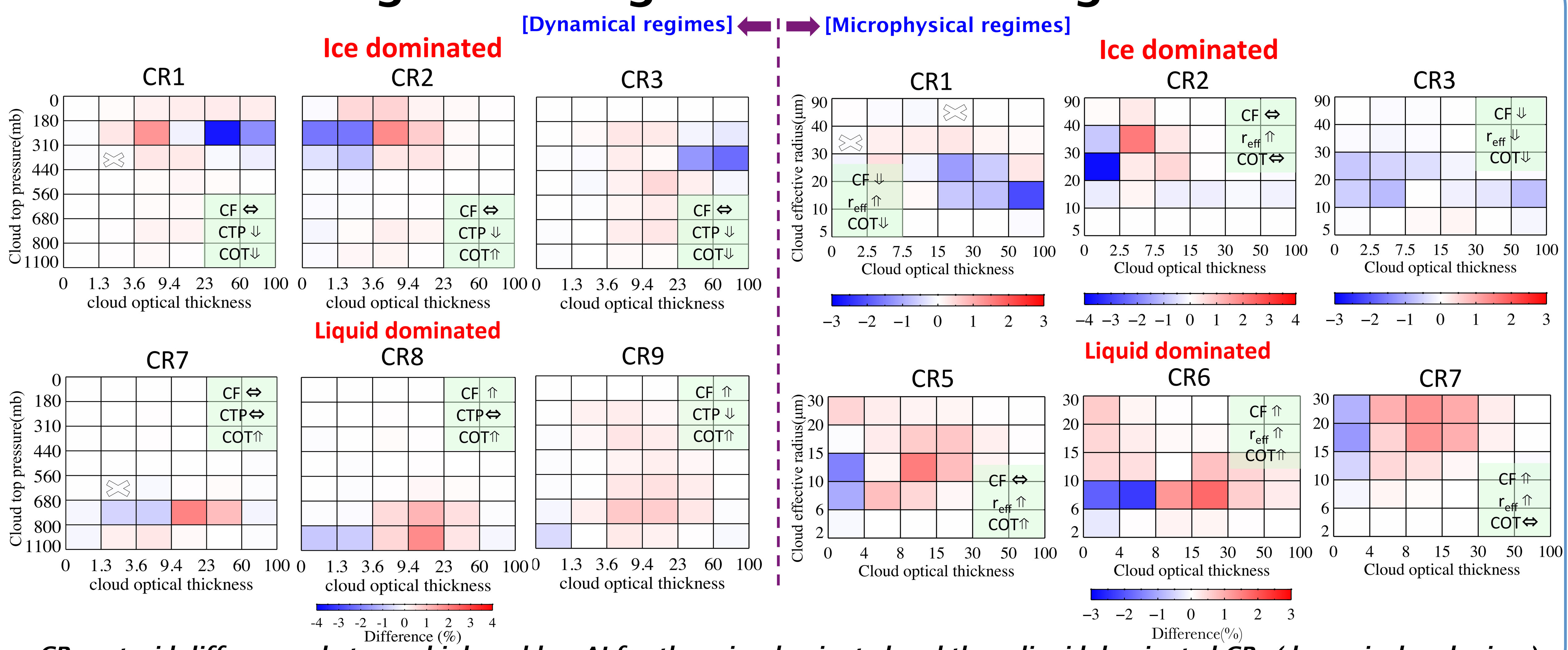
First, we calculated a seasonal cumulative distribution of AI for each gridcell which we break into vigintiles (5% increments). Then we composited spatiotemporally collocated TMPA-3B42 precipitation for each surface precip vigintile, but also for each CR separately. The vertical dashed lines delineate the upper (3Q) and lower (1Q) quartiles. One can see that the dependence of precipitation on AI is distinctly different between land and ocean.

For dynamical regimes, there are clear signals of precipitation increase with AI over land for CR1 and CR10. For the ocean only CR10 may exhibit a slight increase from 1Q to 3Q.

For microphysical regimes, we can see clear signals of precipitation increase with AI over land for several CRs. For the ocean CR1 and CR8 show increase from 1Q to 3Q.

So, from these plots one would conclude that invigoration (if precipitation can be used as a proxy) can be clearly seen over land for both dynamical and micro CRs, but not over ocean.

Regime changes from low to high AI



CR centroid differences between high and low AI for three ice-dominated and three liquid-dominated CRs (dynamical and micro). Red means larger values for high AI and "X" indicates statistically insignificant difference. Overall changes are also provided.

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

This table attempts to summarize our findings. The CRs are separated into those of primarily liquid and primarily ice phase. CR10 (dynamical CRs) and CR8 (microCRs) are listed separately as the contribution of each of the two phases is about the same. The arrow indicates the direction of change (up for increase, down for decrease) when moving to high aerosol (3Q) conditions. Red arrows indicate changes consistent with the invigoration hypothesis, while blue arrows changes consistent with 1st and 2nd indirect effects in liquid clouds. No arrows indicate either statistically insignificant changes, or results that are inconsistent among the members of the CR group. For CR10 and CR8, we do not attempt to categorize the change, but rather only document its direction (increase for all cloud properties under heavier aerosol loading). We can see that invigoration can be better discerned for ice-dominated CRs over land. 1st and 2nd indirect effects can be seen in liquid CRs.