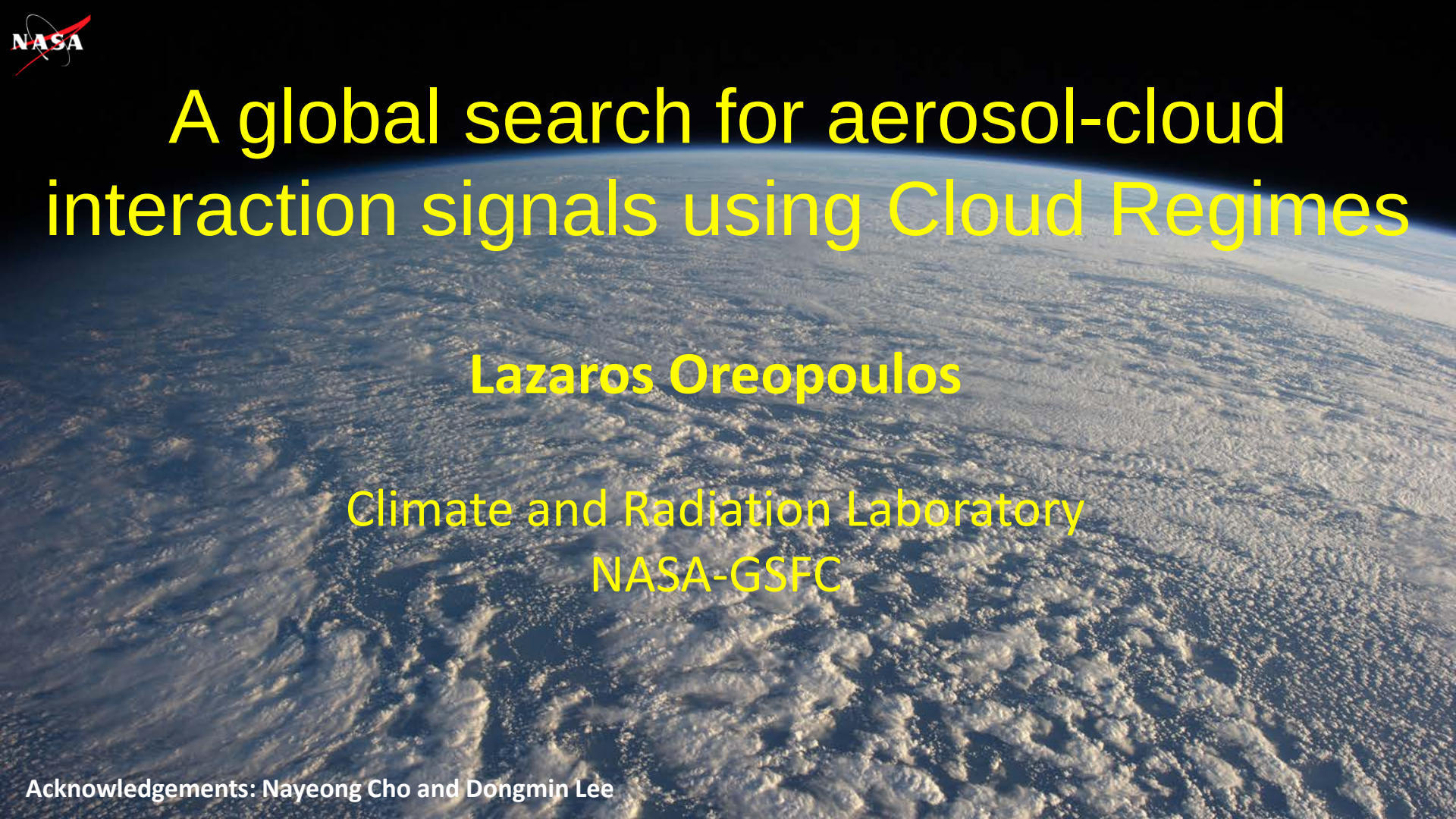

A global search for aerosol-cloud interaction signals using Cloud Regimes

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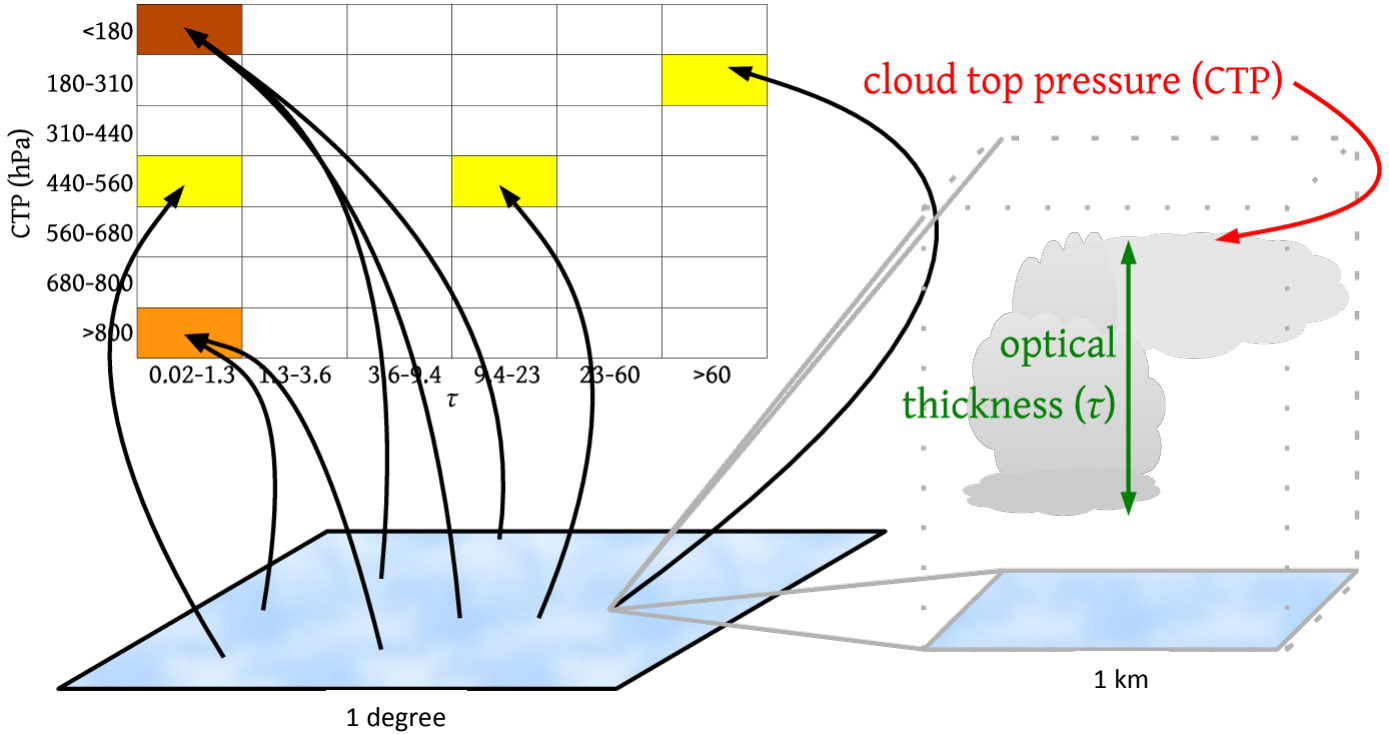
Acknowledgements: Nayeong Cho and Dongmin Lee

Motivation and approach

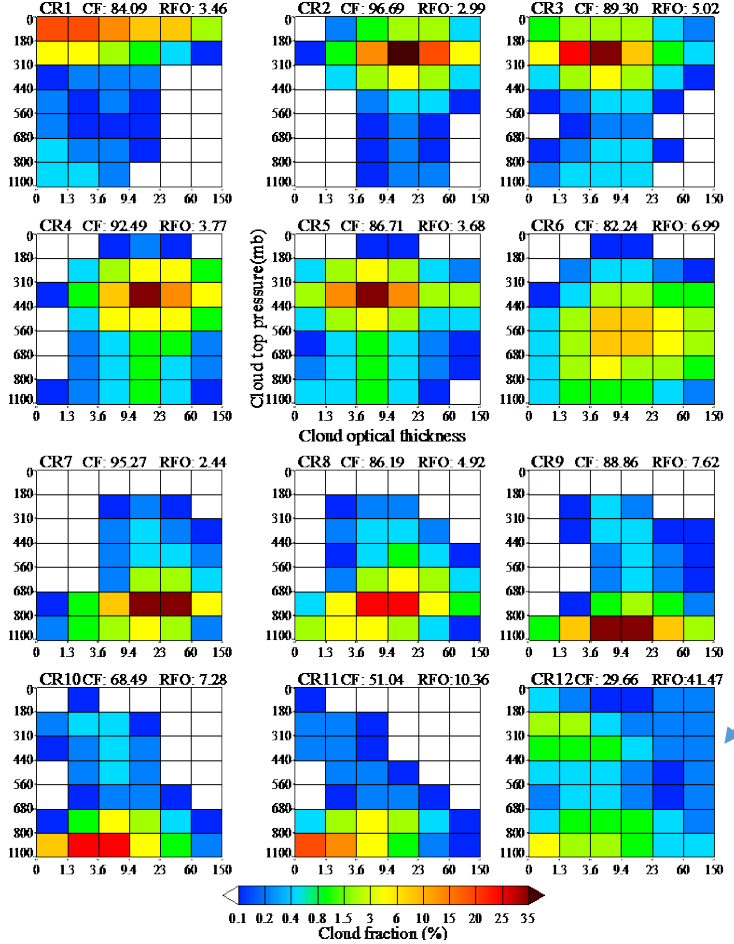
- Interpretation of aerosol-cloud interactions from space is difficult.
- How to separate aerosol from all other effects on clouds?
- Nevertheless, apparent systematic relationships can perhaps be diagnosed at *near-global* scales
- Breakdown by “cloud regime” (CR), a cloud class representative of similar cloud conditions, may help streamline the analysis
- How can regimes be defined?
  - We have previously used CRs from passive observations (MODIS) defined as having alike CTP-COT histograms
  - Should pose <u>some</u> constraint on meteorological conditions

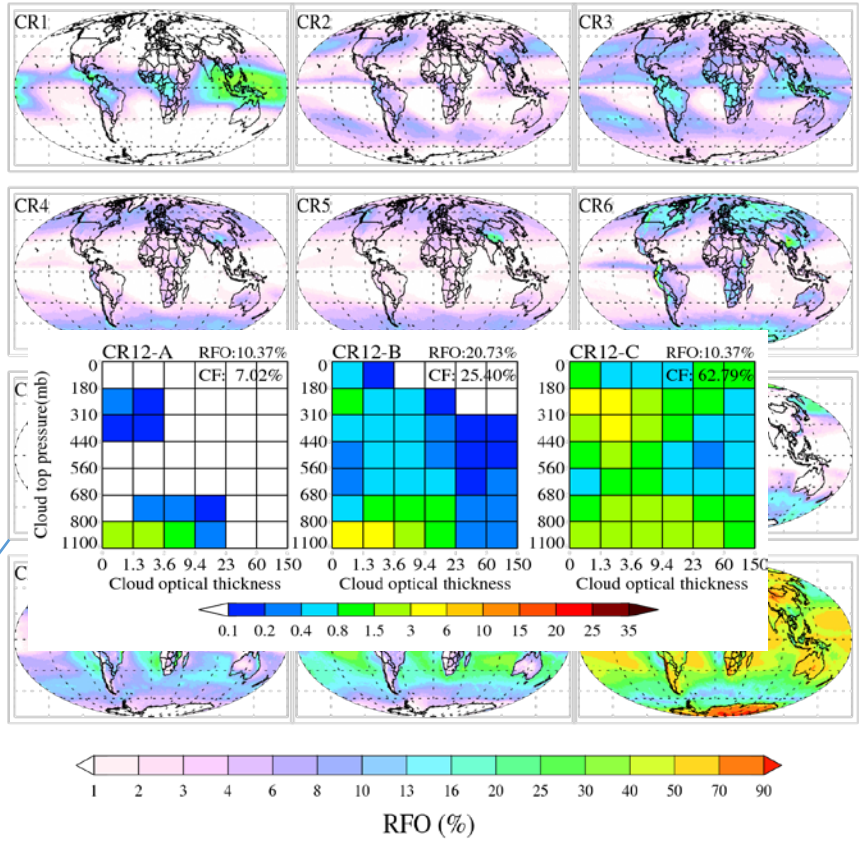
MODIS Joint CTP-COT histograms



Courtesy of Jackson Tan

MODIS Collection 6 Cloud Regimes (CRs)





Radiation/Precipitation signals we are searching for as AOD increases (Classic Paradigms)

Invigoration (ice and mixed CRs, CR1-CR5, CR12)	First indirect effect (FIE) (liquid CRs, CR6-CR11)	Second indirect effect (SIE) (liquid CRs, CR6-CR11)

"Conventional" paradigms (have been under scrutiny)

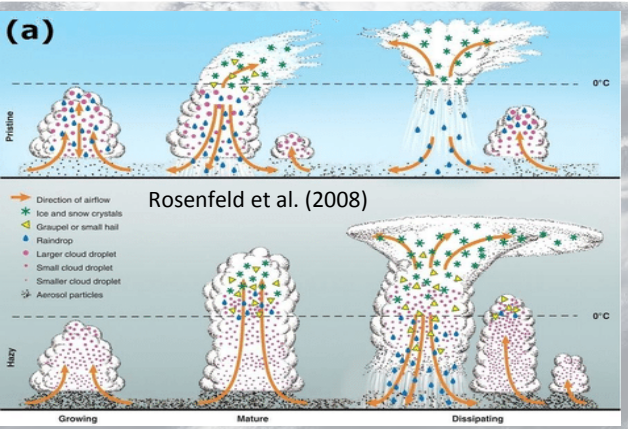
- CF increases
- CTP decreases (CTH increases)
- COT increases
- CRE_SW and CRE_LW increase
- PR and POP increases

- LWP constant
- CER decreases
- COT increases
- CRE_SW increases

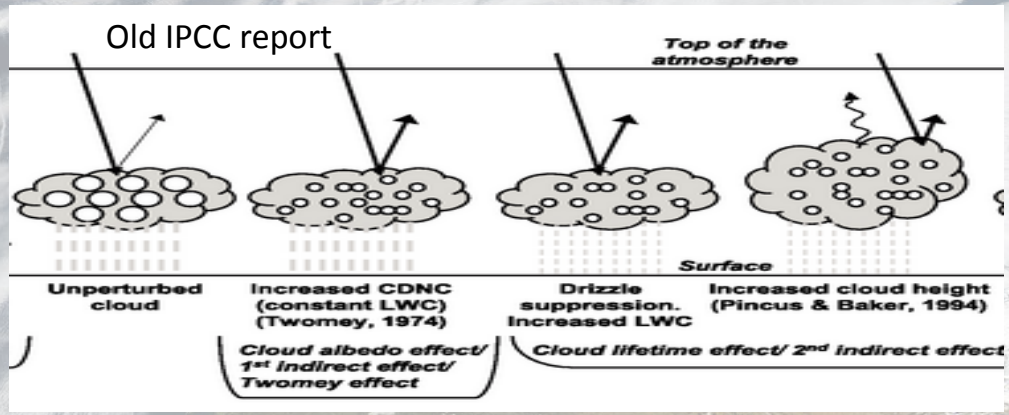
"Twomey"

- PR and POP decrease
- CF increases
- LWP increases
- COT increases
- CRE_SW and CRE_LW increase

"Lifetime"



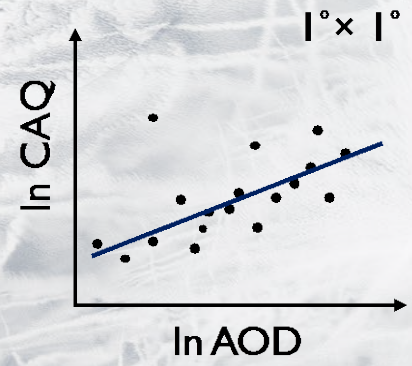
Rosenfeld et al. (2008)



Local sensitivities, methodology

- For *each grid cell* calculate the sensitivity (S_{CAQ}) of an afternoon cloud-affected quantity (CAQ) to morning AOD:

$$S_{CAQ} = \frac{dln(CAQ)}{dln(AOD)}$$



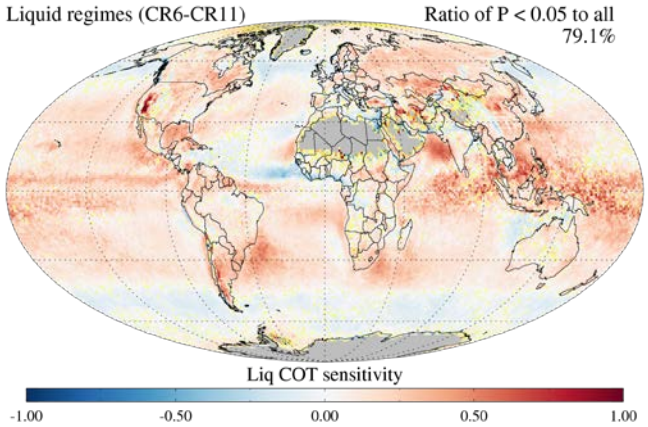
- Slope of linear regression of $lnCAQ\ vs. lnAOD$ *separately for each* group (”ice”, ”mixed”, “liquid”) of morning CRs (separate regression for each CR12 subregime)
- Each point in the scatterplot represents a distinct morning CR occurrence.
- We do not care what afternoon CR the CAQ corresponds to

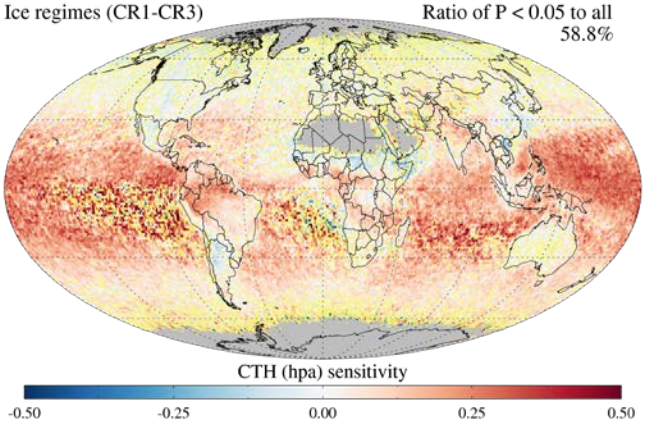
Caveats

- Is AOD appropriate?
  - AI=AOD×AE is not always available (MERRA2 and MODIS-land)
  - Strictly speaking, CCN(z)/IN(z) are most appropriate
- Aerosol in the neighborhood of clouds problematic
  - Sampling issue for MODIS
- Time delay between Terra and Aqua vs timescale of interaction
- Meteorological influences
  - How much do CRs constrain?
  - Have looked into this, will not show today

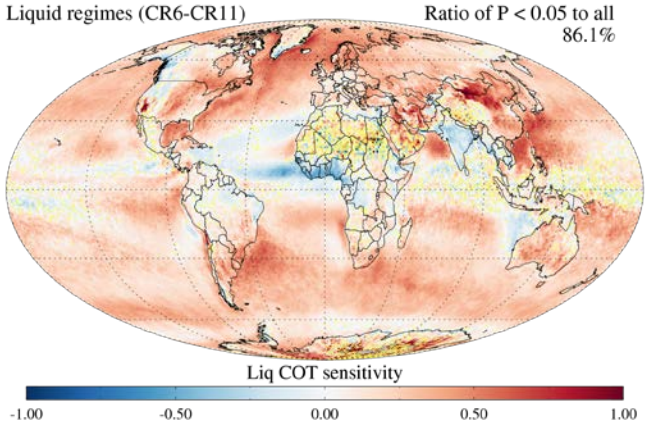
Some examples

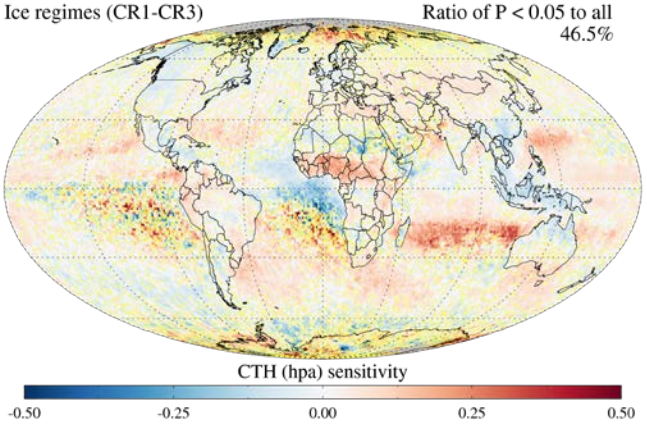
MODIS AOD





MERRA2 AOD

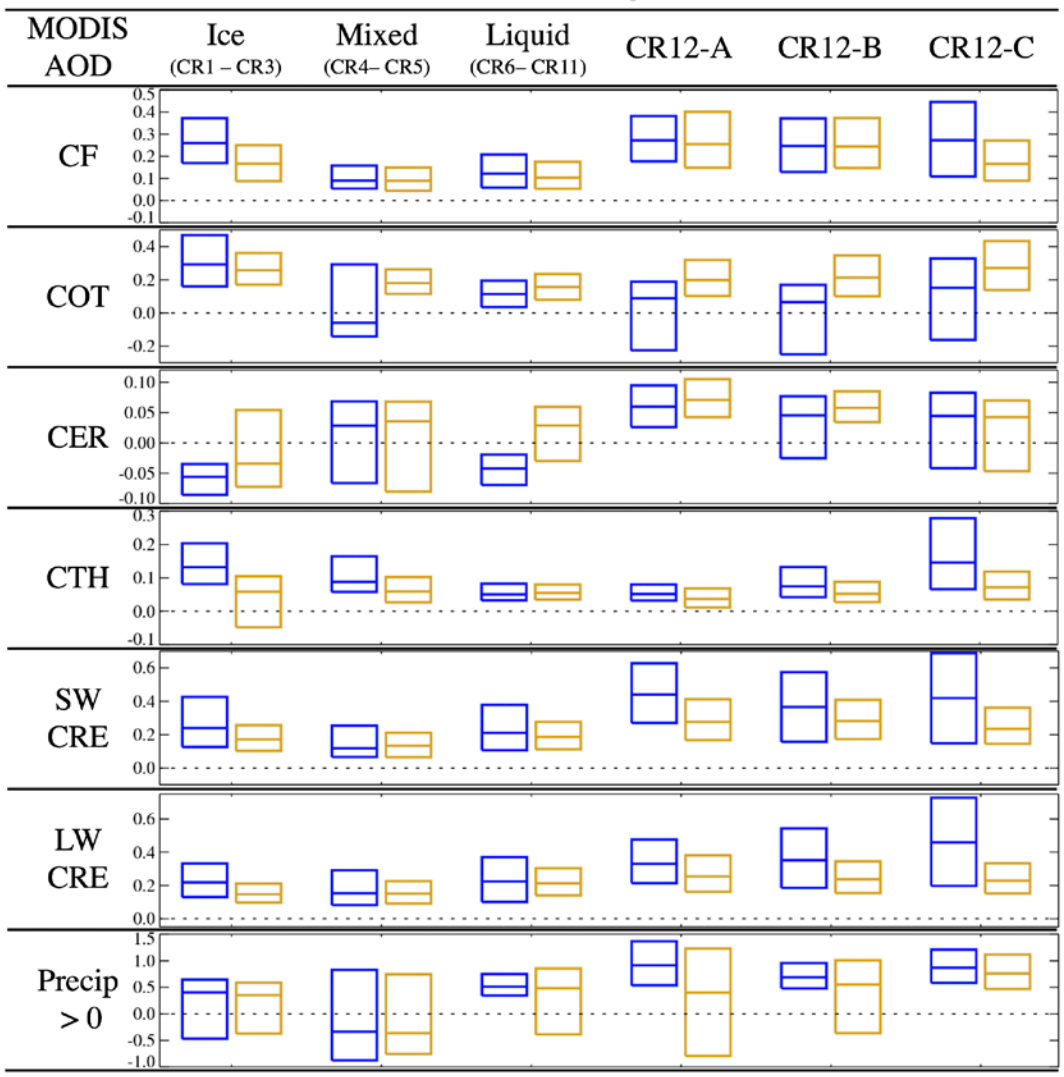




Gray: Fewer than 5 points available

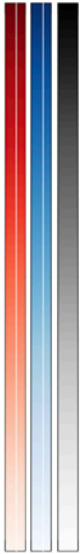
Yellow shading: Failed F-test for goodness of fit at 95% confidence level.

Sensitivity boxplots, MODIS AOD



Sensitivity signs, MODIS and MERRA-2 AOD

MODIS AOD	Ice (CR1 – CR3)		Mixed (CR4– CR5)		Liquid (CR6– CR11)		CR12-A		CR12-B		CR12-C	
	Ocean	Land	Ocean	Land	Ocean	Land	Ocean	Land	Ocean	Land	Ocean	Land
CF	+	+	+	+	+	+	+	+	+	+	+	+
COT	+	+	–	+	+	+	+	+	+	+	+	+
CER	–	–	+	+	–	+	+	+	+	+	+	+
CTH	+	+	+	+	+	+	+	+	+	+	+	+
SW CRE	+	+	+	+	+	+	+	+	+	+	+	+
LW CRE	+	+	+	+	+	+	+	+	+	+	+	+
Precip * > 0	+	+	–	–	+	+	+	+	+	+	+	+



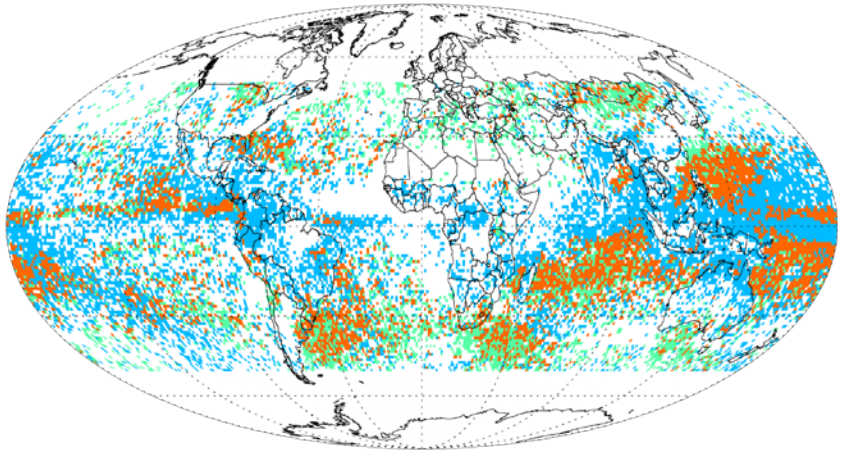
MERRA AOD	Ice (CR1 – CR3)		Mixed (CR4– CR5)		Liquid (CR6– CR11)		CR12-A		CR12-B		CR12-C	
	Ocean	Land	Ocean	Land	Ocean	Land	Ocean	Land	Ocean	Land	Ocean	Land
CF	+	+	+	+	+	+	+	+	+	+	+	+
COT	+	+	+	+	+	+	+	+	+	+	+	+
CER	–	–	–	–	–	–	+	+	+	+	+	–
CTH	+	+	+	+	+	+	+	+	+	+	+	+
SW CRE	+	+	+	+	+	+	+	+	+	+	+	+
LW CRE	+	+	+	+	+	+	+	+	+	+	+	+
Precip * > 0	+	–	+	–	+	+	+	–	+	–	+	+

Shades or red: Consistent with invigoration

Shades of blue: Consistent with FIE/SIE

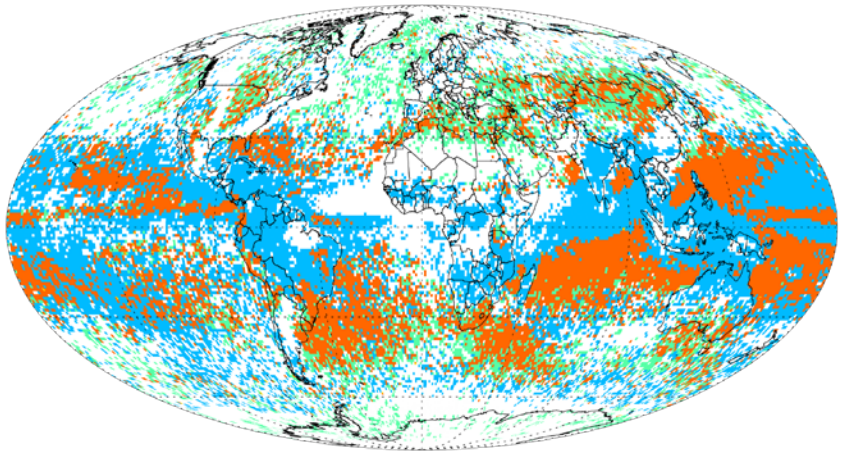
Lighter shades indicate poorer sampling

Invigoration (Ice CRs)



$S_{PR} > 0$ & $S_{CF} > 0$ & $S_{CTH} > 0$ & $S_{COT} > 0$ & $S_{CRE} > 0$

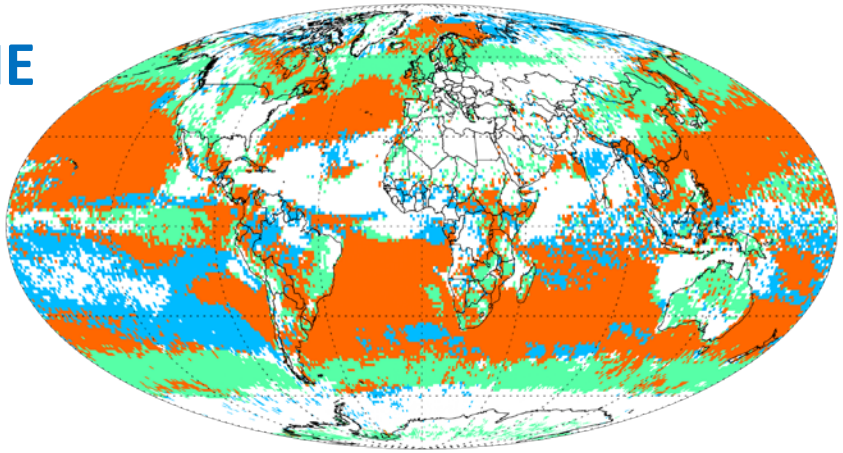
Both MERRA and MODIS AOD
MODIS only
MERRA only



$S_{CF} > 0$ & $S_{CTH} > 0$ & $S_{COT} > 0$ & $S_{CRE} > 0$

Liquid CRs

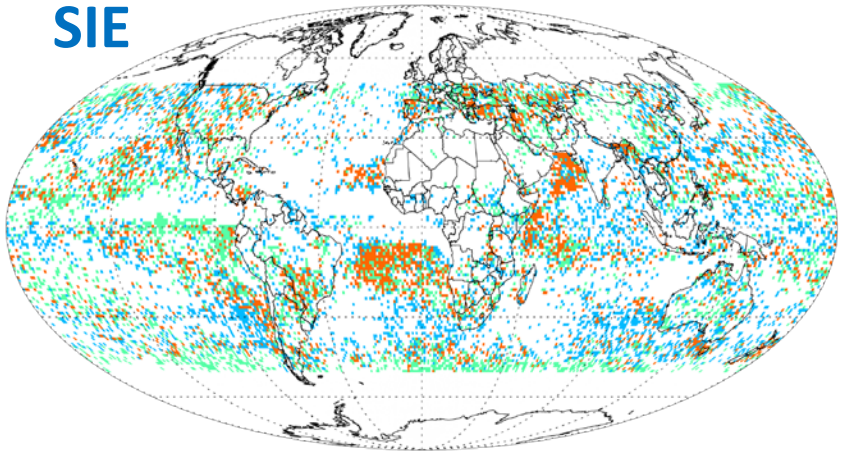
FIE



Both MERRA and MODIS AOD
MODIS only
MERRA only

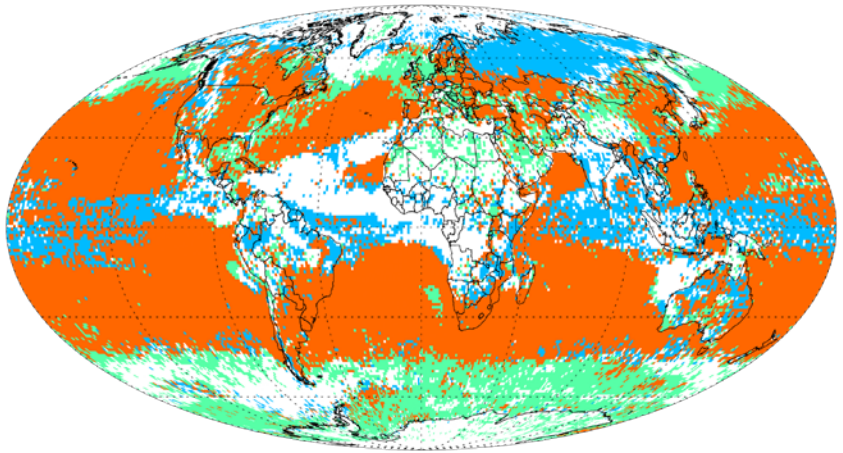
$S_{CER} < 0$ & $S_{COT} > 0$ & $S_{CRESW} > 0$

SIE



$S_{PR} < 0$ & $S_{CF} > 0$ & $S_{COT} > 0$ & $S_{CRE} > 0$

SIE, no precipitation



$S_{CF} > 0$ & $S_{COT} > 0$ & $S_{CRE} > 0$

Take-home messages

- A Regime-based approach is promising for *diagnosis* of aerosol-cloud-precipitation interactions at global scales
- This type of global analysis (most extensive ever?) will *not* capture nuances and full range of interactions, but will give a robust overall picture
- Morning aerosol vs afternoon cloud is possible with Terra-Aqua and MERRA2
  - Aerosol sampling limitations due to cloud presence can be overcome with MERRA2
  - MERRA2 can also assist with incorporating meteorological influences
  - MODIS-MERRA2 result comparison perhaps can tell us about result robustness
- Most results consistent with paradigms, especially for liquid CRs
  - Precipitation is the most noisy and inconclusive
- See Oreopoulos et al. JGR (2017) as a starting point; new paper in preparation.

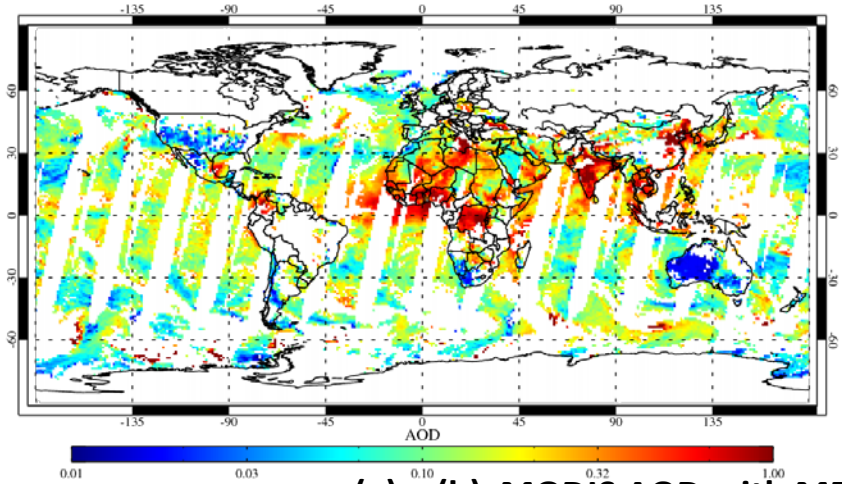

Questions?

Additional Slides

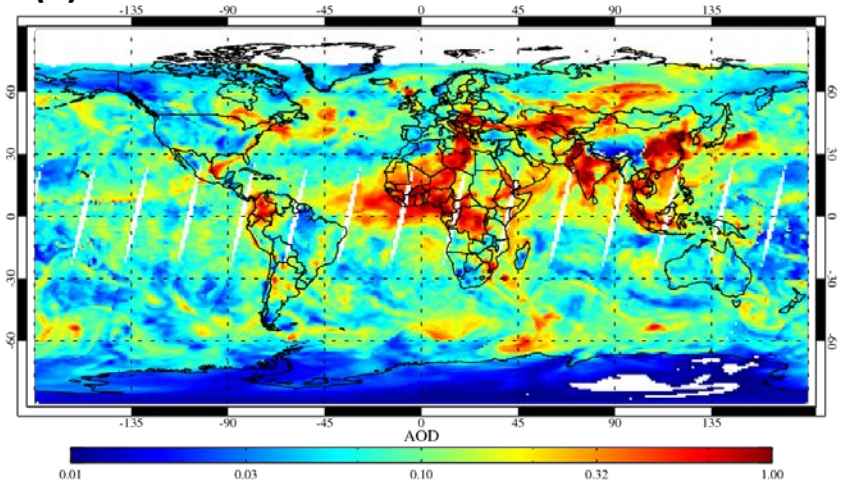
Sampling when cloudy

(a) MODIS AOD

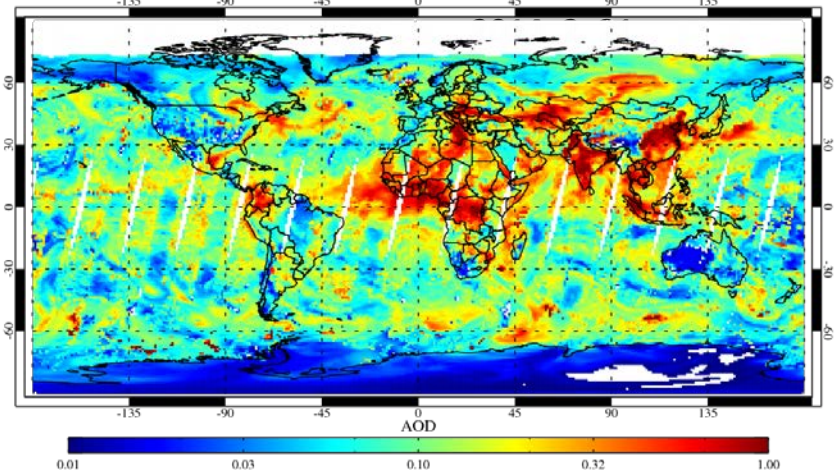
(2014.2.21)



(b) MERRA2 AOD

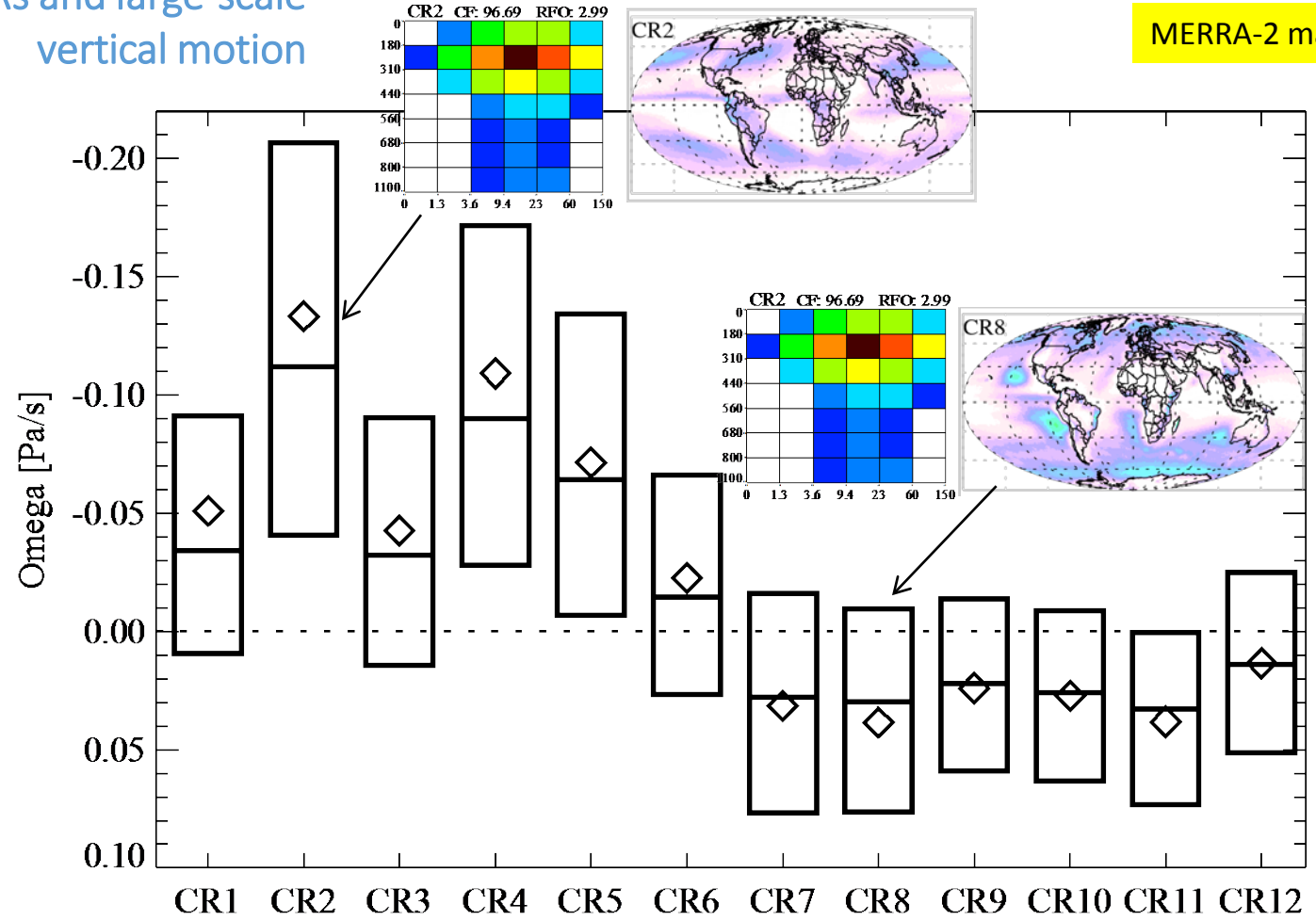


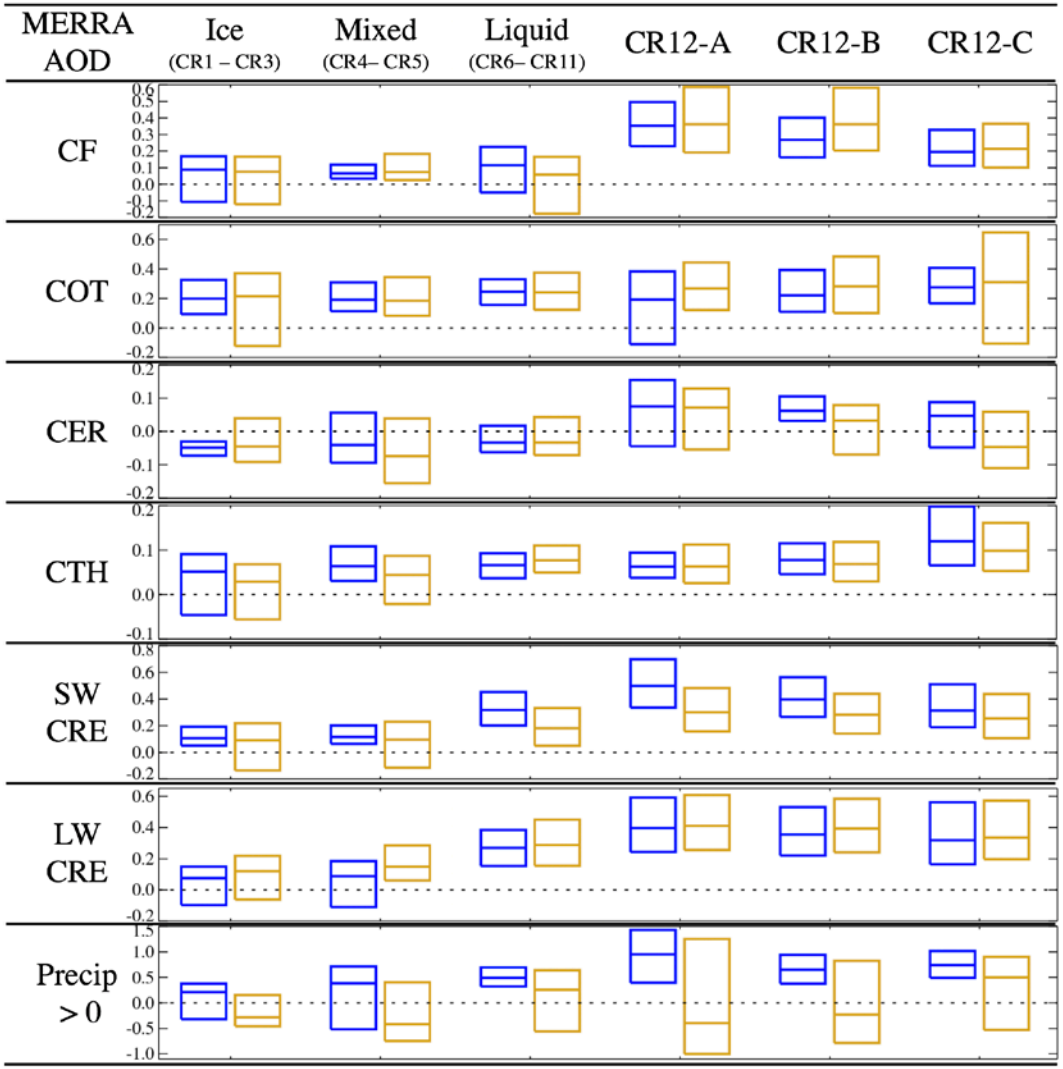
(a) + (b) MODIS AOD with MERRA2-filled



CRs and large-scale vertical motion

MERRA-2 matched to MODIS




MERRA AOD
Ice (CR1 – CR3)
Mixed (CR4– CR5)
Liquid (CR6– CR11)
CR12-A
CR12-B
CR12-C
CF
COT
CER
CTH
SW CRE
LW CRE
Precip > 0