Cloud Radiative Effect breakdown by regime and vertical structure

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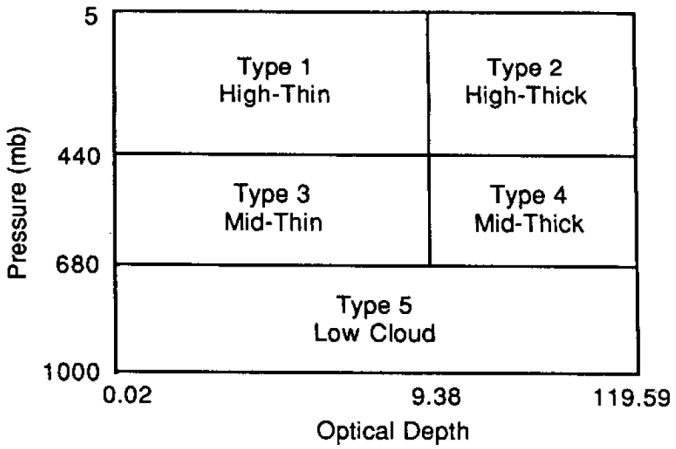
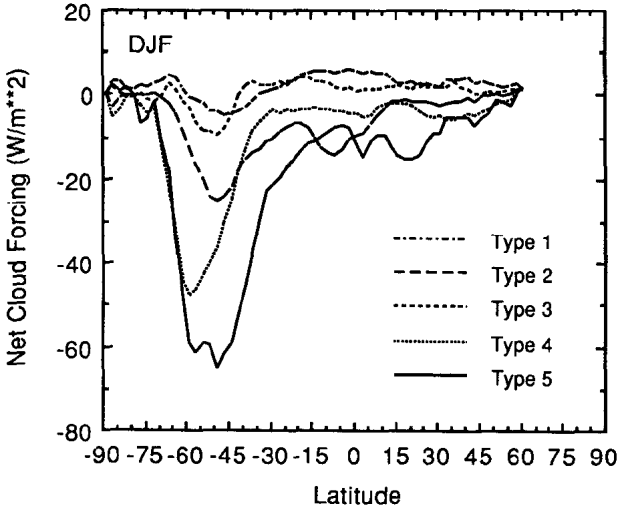
Previous Efforts

Breakdown of radiation and precip by cloud "type"



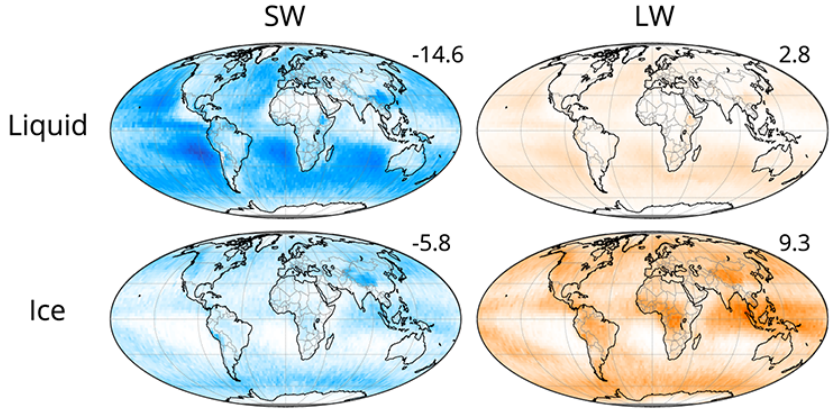
ERBE-ISCCP

Hartmann et al. 1992



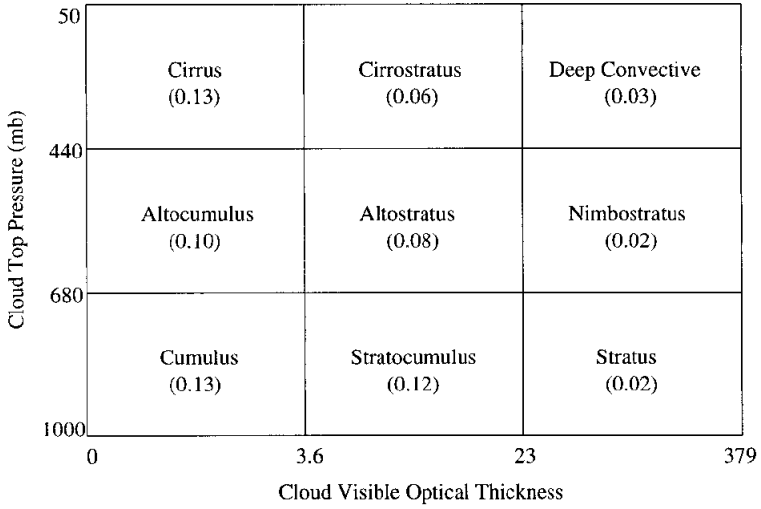
Chen et al. 2000

Matus and L'Ecuyer 2017



(by phase)

CloudSat-CALIPSO



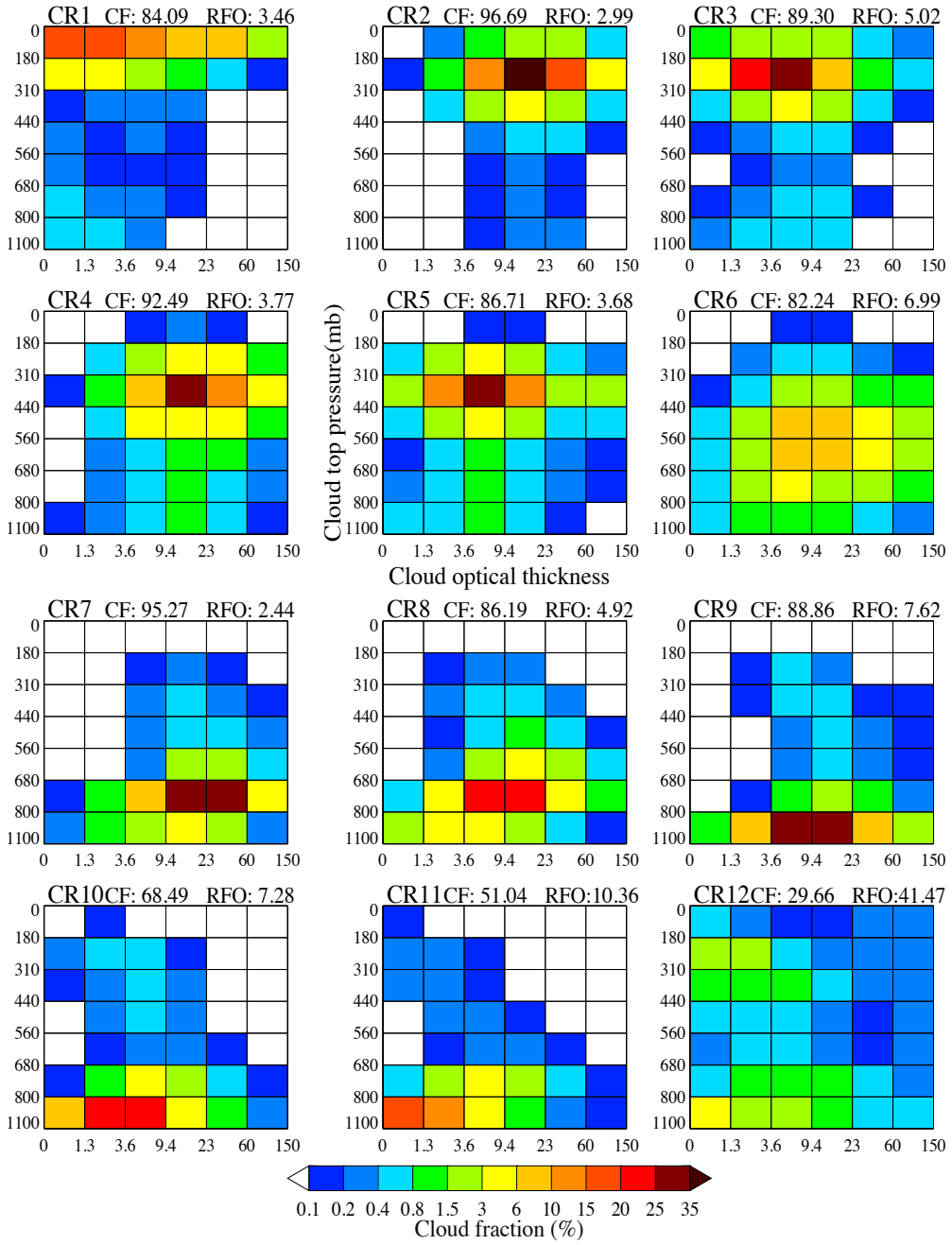
ISCCP

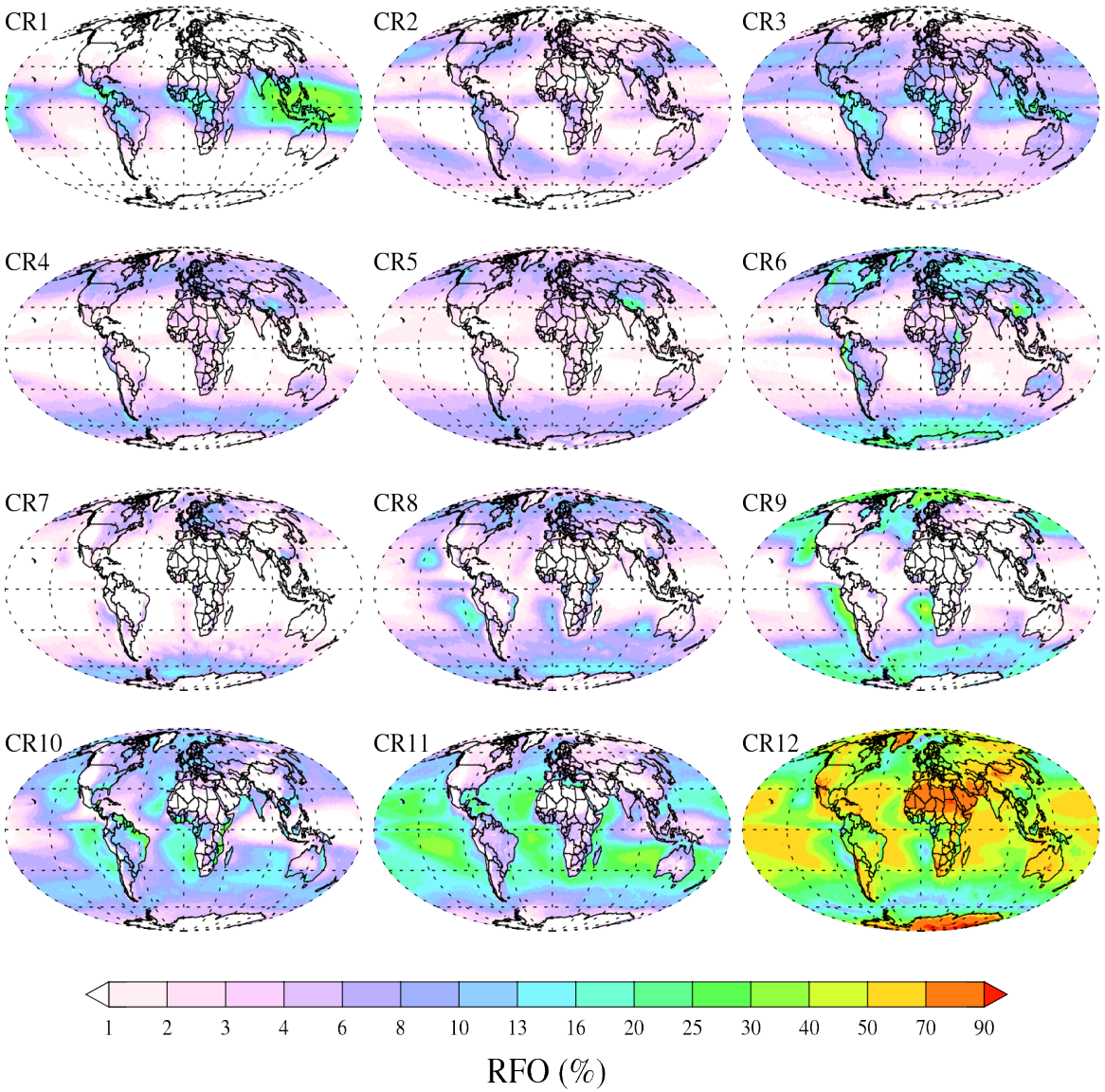
Cloud type	TOA SW	TOA LW	TOA TL
Cirrus	−4.2	5.5	1.3
Cirrostratus	−7.9	5.5	−2.4
Deep convective	−6.2	2.9	−3.3
Altocumulus	−3.2	1.5	−1.7
Altostratus	−8.3	2.0	−6.3
Nimbostratus	−3.4	0.7	−2.7
Cumulus	−5.2	0.6	−4.6
Stratocumulus	−12.7	1.2	−11.5
Stratus	−2.4	0.2	−2.2
Sum (true)	−53.5	20.1	−33.4

Cloud "types" or cloud "regimes"/"mixtures"?

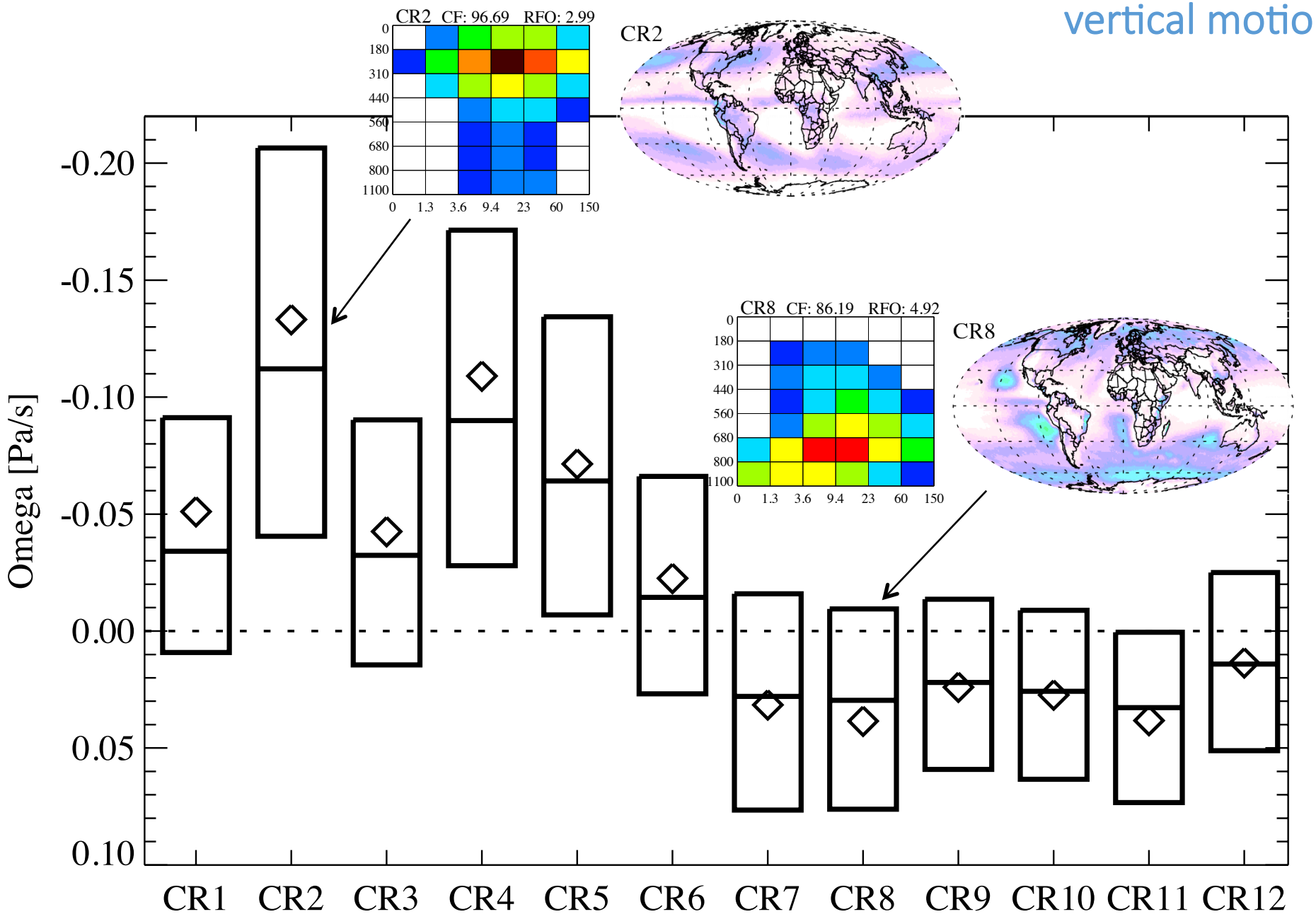
Cloud Regimes (CRs)

MODIS C6 CRs


CR1 CF: 84.09 RFO: 3.46
CR2 CF: 96.69 RFO: 2.99
CR3 CF: 89.30 RFO: 5.02
CR4 CF: 92.49 RFO: 3.77
CR5 CF: 86.71 RFO: 3.68
CR6 CF: 82.24 RFO: 6.99
CR7 CF: 95.27 RFO: 2.44
CR8 CF: 86.19 RFO: 4.92
CR9 CF: 88.86 RFO: 7.62
CR10CF: 68.49 RFO: 7.28
CR11CF: 51.04 RFO:10.36
CR12CF: 29.66 RFO:41.47
Cloud top pressure(mb)
0 180 310 440 560 680 800 1100
0 1.3 3.6 9.4 23 60 150
Cloud optical thickness
0.1 0.2 0.4 0.8 1.5 3 6 10 15 20 25 35
Cloud fraction (%)


CR1
CR2
CR3
CR4
CR5
CR6
CR7
CR8
CR9
CR10
CR11
CR12
1 2 3 4 6 8 10 13 16 20 25 30 40 50 70 90
RFO (%)

CRs and large-scale vertical motion



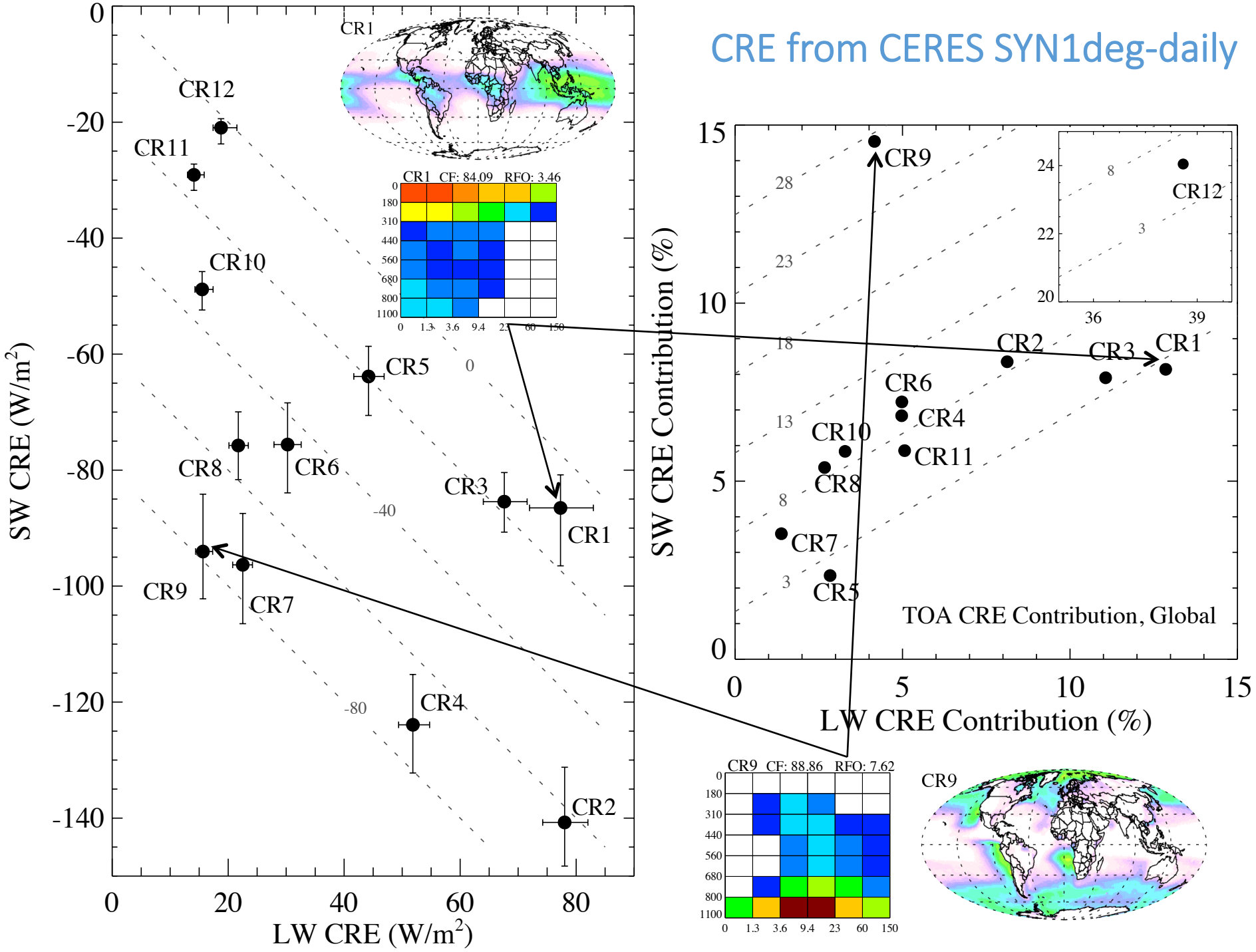
CR Cloud Radiative Effects

(Oreopoulos et al., JGR 2016)

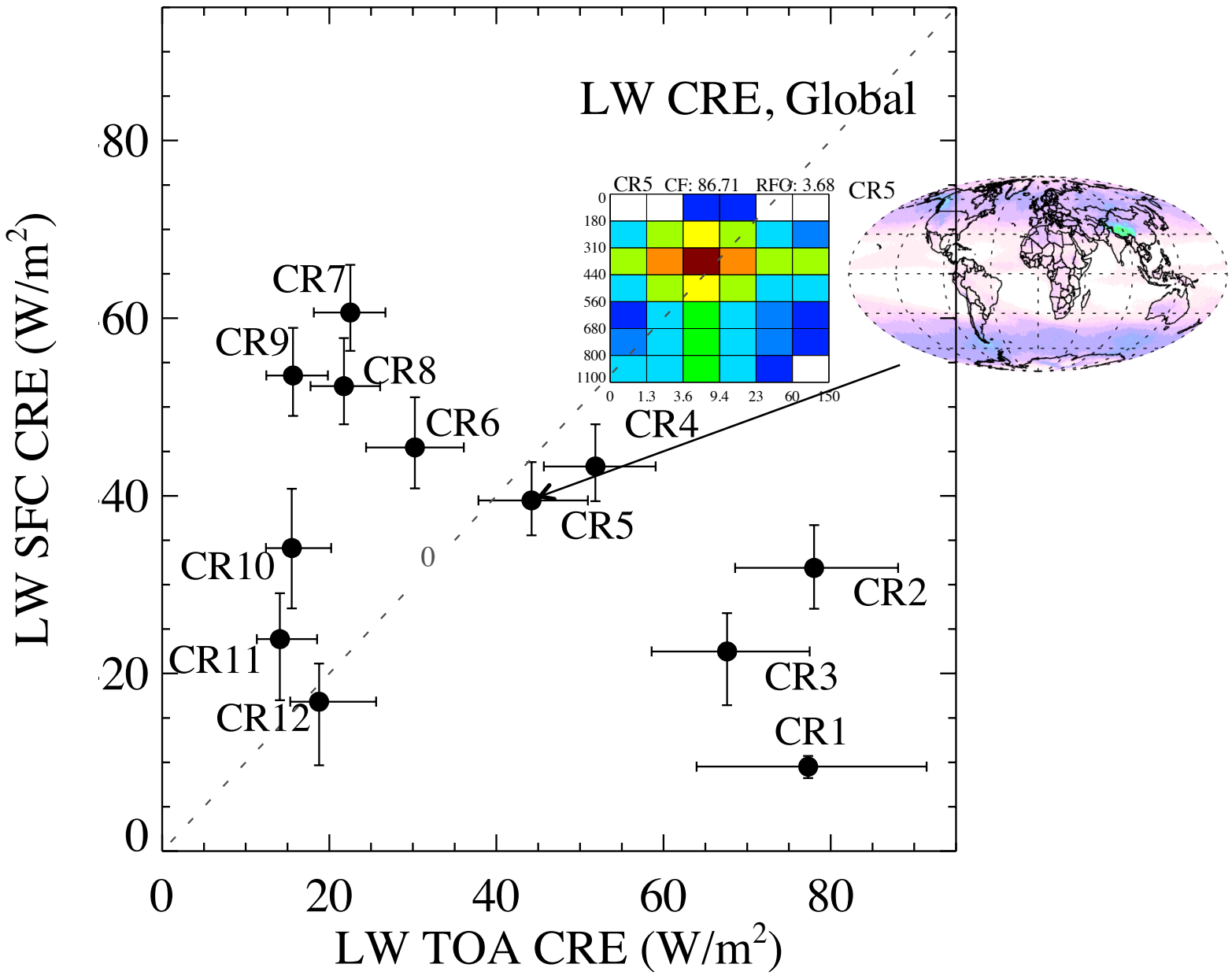
Dataset and methodology

- 12 years of Aqua-Terra L-3 daily (D3) 1° data
  - Collection 6
- Joint histograms of CTP-TAU
- MODIS CRs from *k-means* clustering
- $CRE = F_{all\text{-}sky} - F_{clr} = CF(F_{ovc} - F_{clr})$
  - F is net=down-up flux
- From CERES SYN1deg Ed3A (daily or 3hr), 2B-FLXHR-LIDAR R04 (CloudSat/CALIPSO), AIRS V6 L3 (LW TOA only)
- Composite CRE onto MODIS CRs
  - Some subtleties depending on dataset

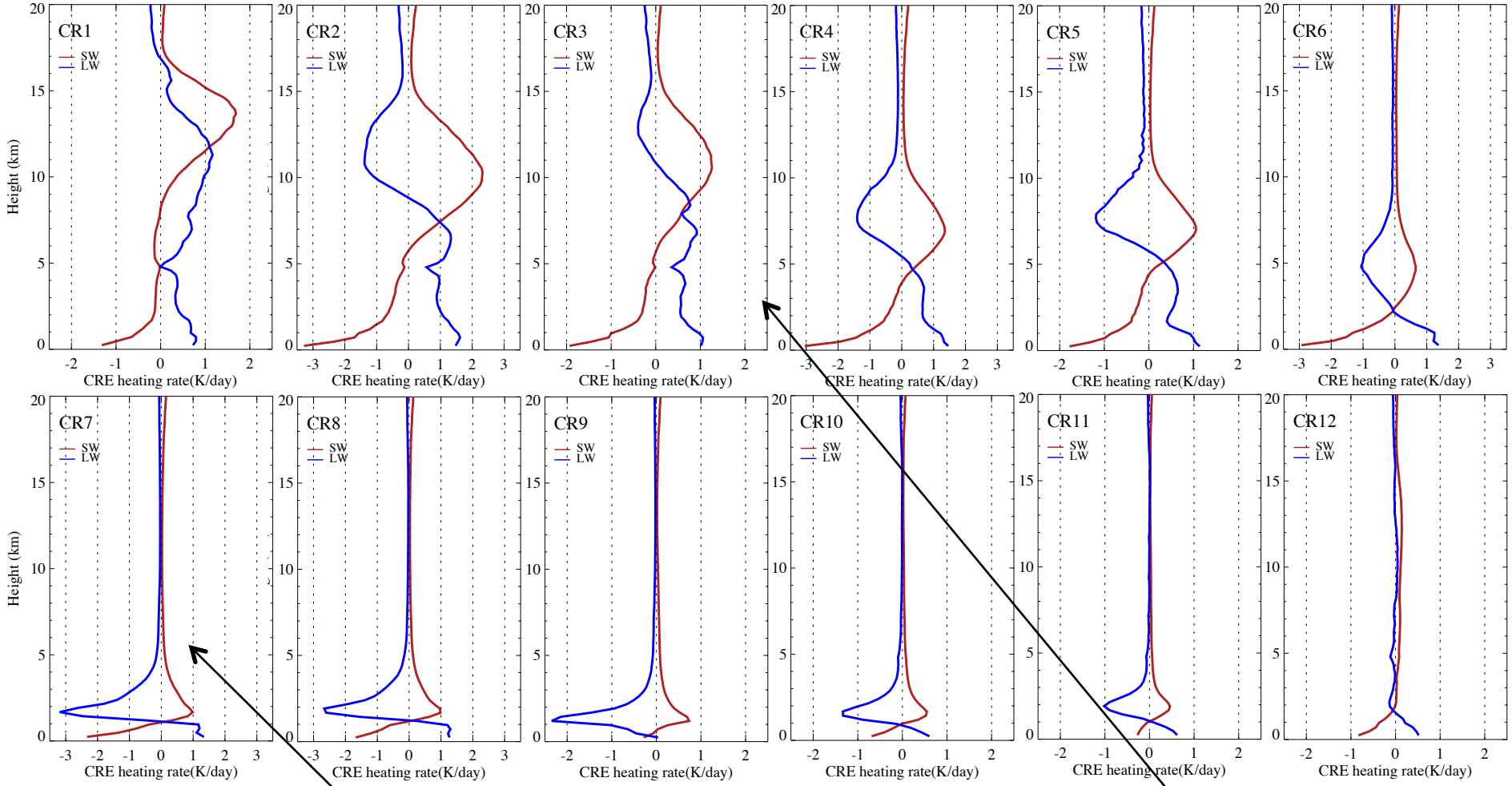
CRE from CERES SYN1deg-daily

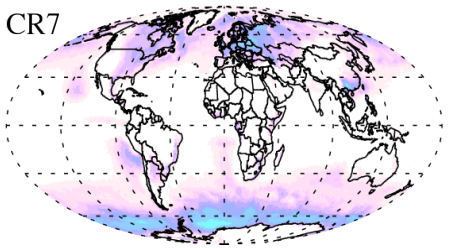


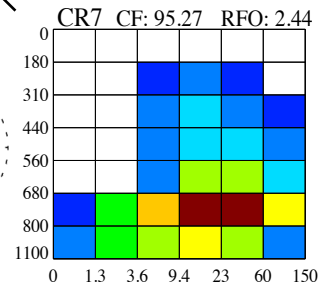
Cooling vs Warming CREs



Vertical distribution of cooling and warming (SW and LW)

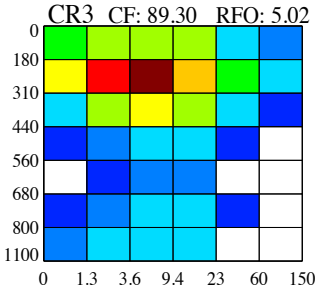


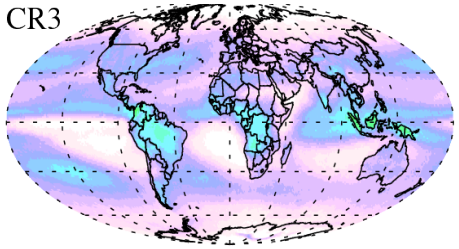




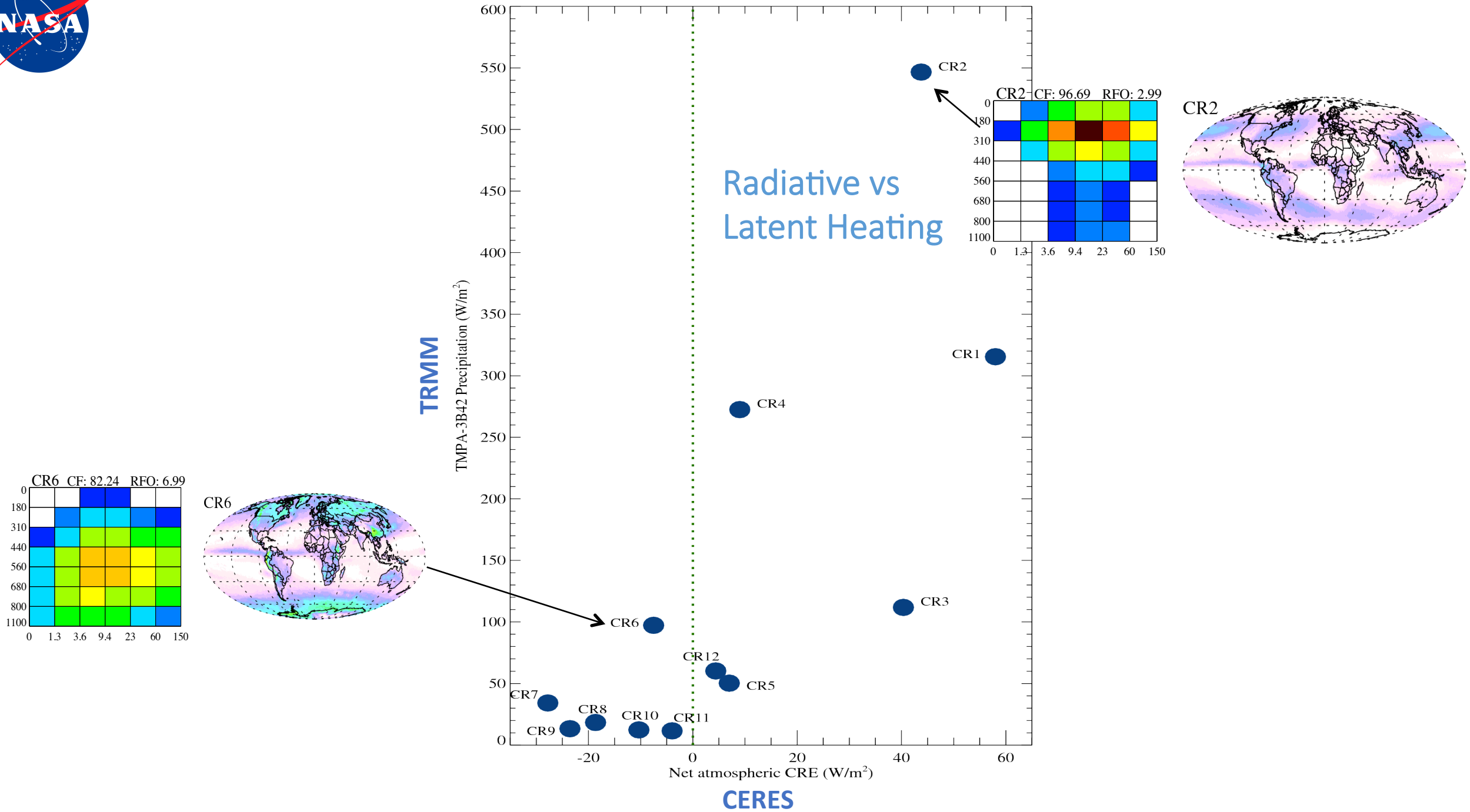
$$CRH = -\frac{1}{\rho C_p}\frac{dCRE}{dz}$$

CloudSat-CALIPSO
(2B-FLXHR-LIDAR)

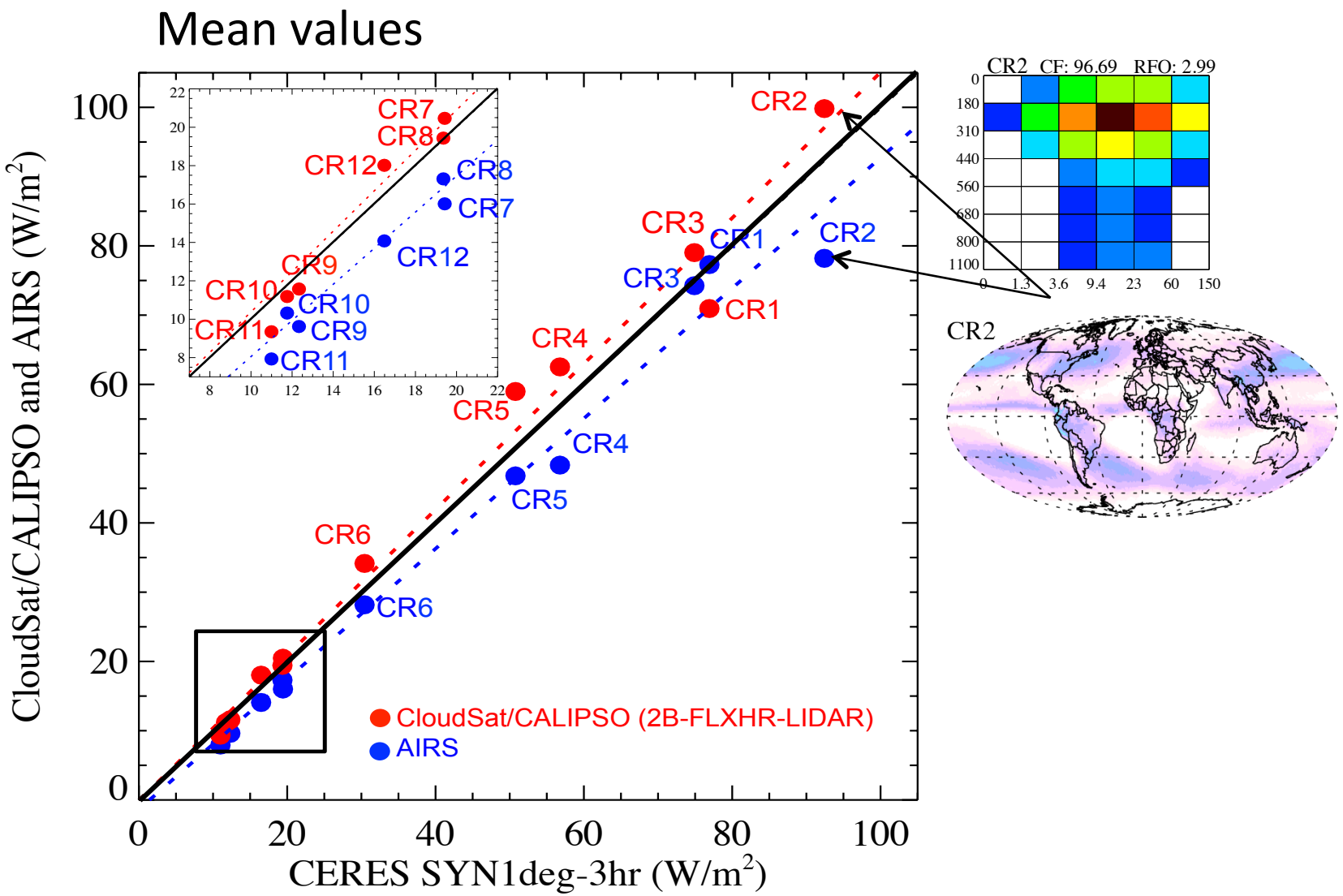




Radiative vs Latent Heating



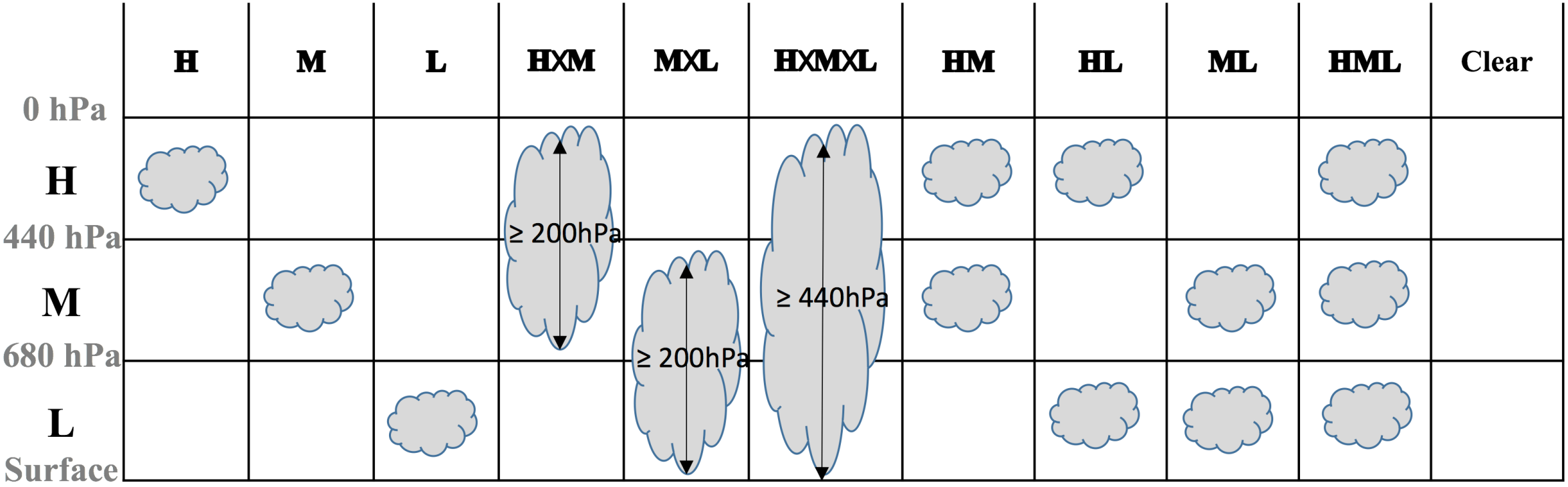
LW TOA CRE comparison for Aqua CRs



Cloud Vertical Structures (CVSs)

Simplified Cloud Vertical Structures

(from 2B-CLDCLASS-LIDAR)



Similar to Tselioudis et al. 2013

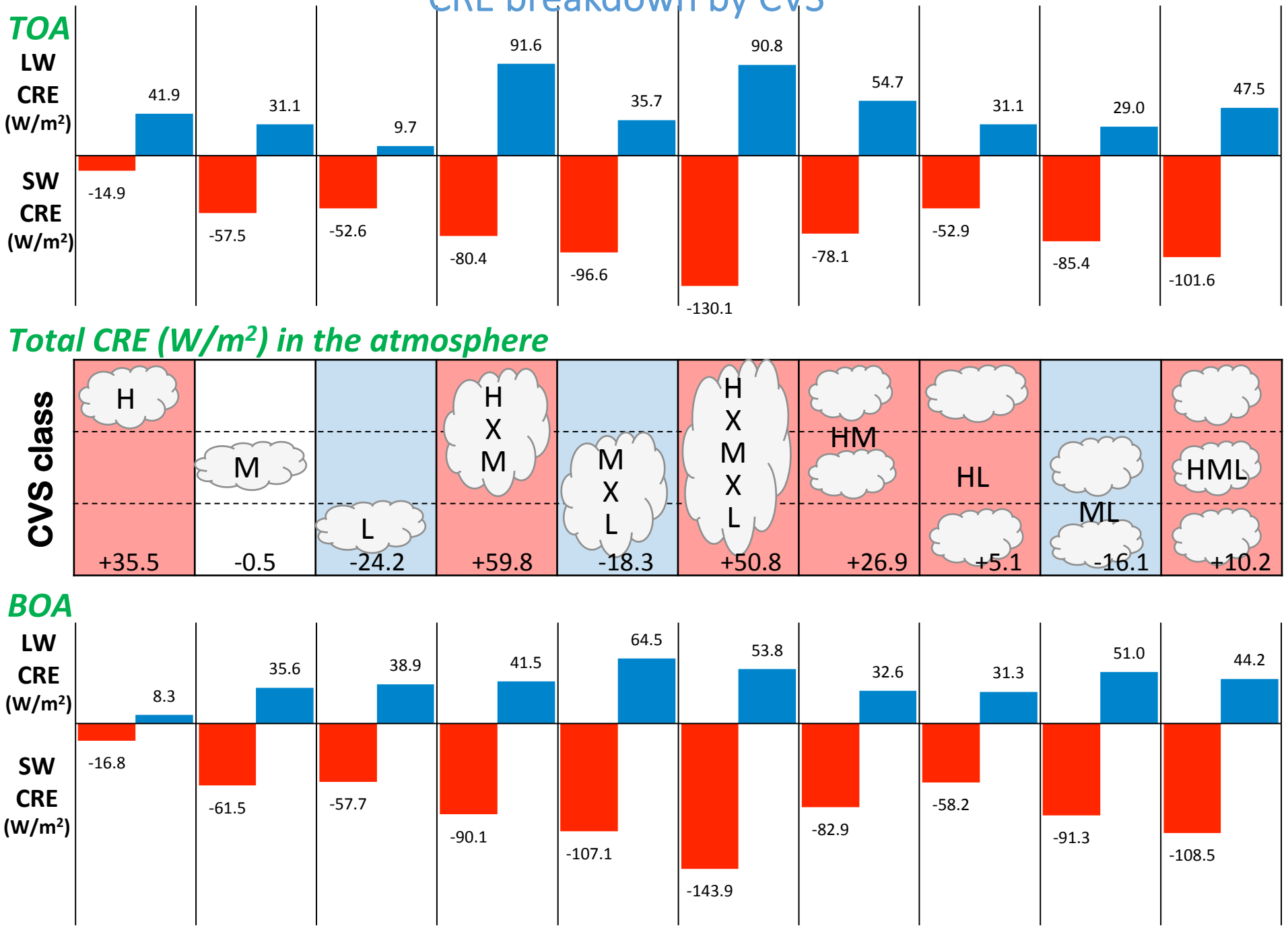
CVS Cloud Radiative Effects

(Oreopoulos et al., JGR 2017, in review)

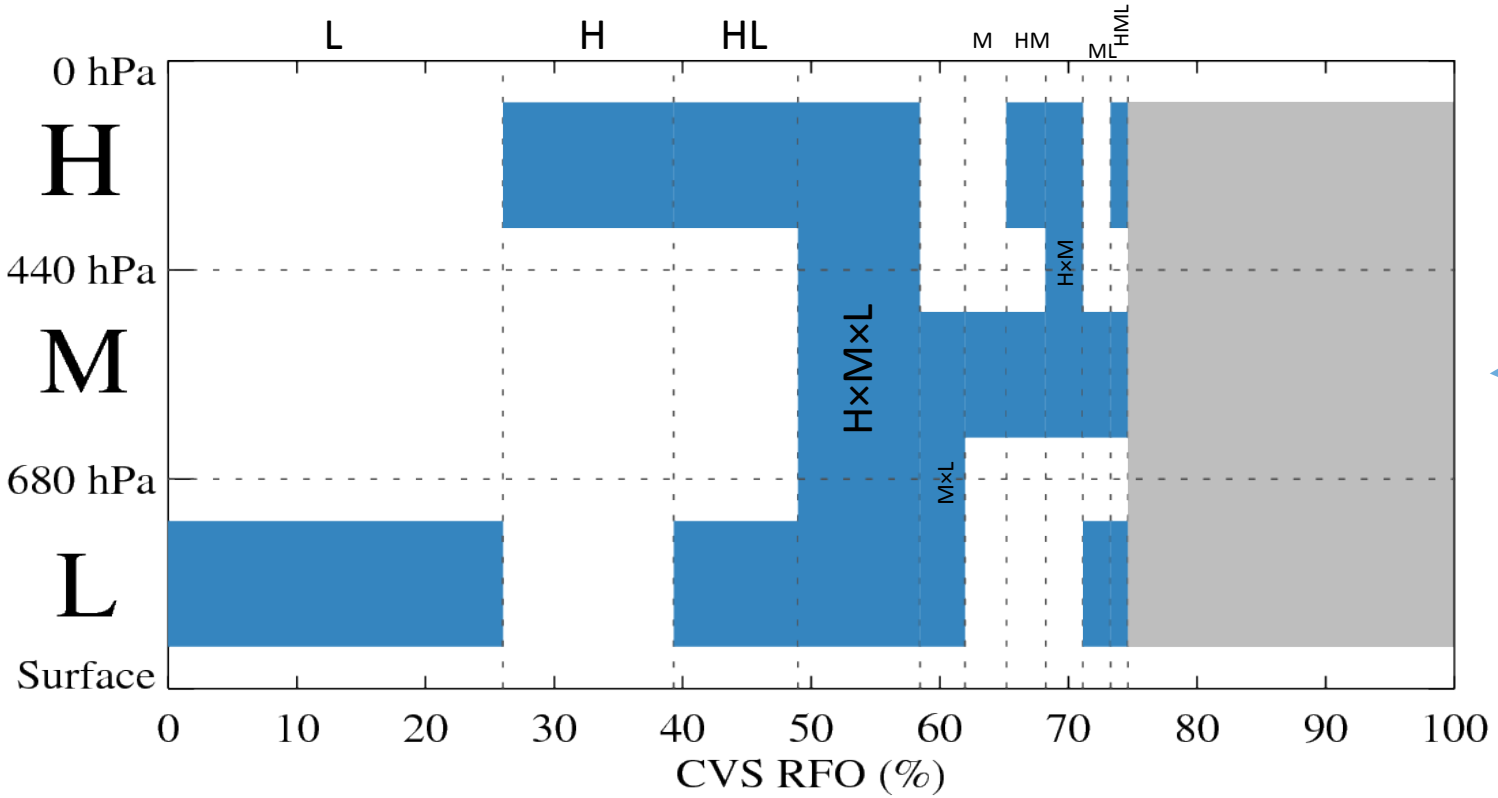
Dataset and methodology

- Four years (2007-2010) of the merged CloudSat/CALIPSO product 2B-CLDCLASS-LIDAR R04
  - Atmospheric profiles 1.4x1.8 $(km)^2$ (horizontal) and 240 m (vertical), 82°S to 82°N.
  - Heights of hydrometeor layer top and base in each profile
- MODIS CVSs from adopting standard layers and judicial simplification
- Coincident 2B-FLXHR-LIDAR R04 data
  - SW and LW CREs at TOA and BOA
  - Crude scaling of SW to convert to diurnal average
- Average CREs for each CVS class

CRE breakdown by CVS



CVS contribution to CRE



Global frequency of CVS classes

% contribution of each CVS class, except last column (Wm^{-2})

CVS class	RFO	SWTOA	LWTOA	SWBOA	LWBOA	totATM
L	26.0	31.2	9.9	31.1	39.7	-8.9
H	13.3	4.2	20.1	4.3	4.0	6.2
HL	9.7	10.3	10.4	10.3	10.3	0.6
H×M×L	9.5	26.2	31.3	26.4	18.7	6.3
M×L	3.5	7.5	4.8	7.6	8.7	-0.9
M	3.2	4.3	4.0	4.2	4.6	0.0
HM	3.0	4.4	5.2	4.2	3.1	0.9
H×M	2.9	5.0	9.7	5.1	4.4	2.3
ML	2.2	4.2	2.4	4.1	4.3	-0.5
HML	1.4	2.8	2.2	2.7	2.1	0.2

Summary and parting thoughts

- CRs and CVSs help us understand the contributions of the various prevailing cloud systems to the Earth Radiation budget
- Coherent picture between interpretation of the makeup of CRs/CVSs and their radiative character
- CRs and CVSs good framework to:
  - recognize cloud systems that systematically provide radiative cooling or warming of the atmosphere
  - resolve vertical distribution of cooling/warming
  - discern relative importance of cloud systems in enhancing (reducing) reflected (transmitted) solar to space (surface) and reducing (increasing) emitted thermal IR to space (surface)
- A-Train makes compositing and comparisons more meaningful!