Development of comprehensive metrics for regime-based evaluation of cloud distributions in CMIP5 models

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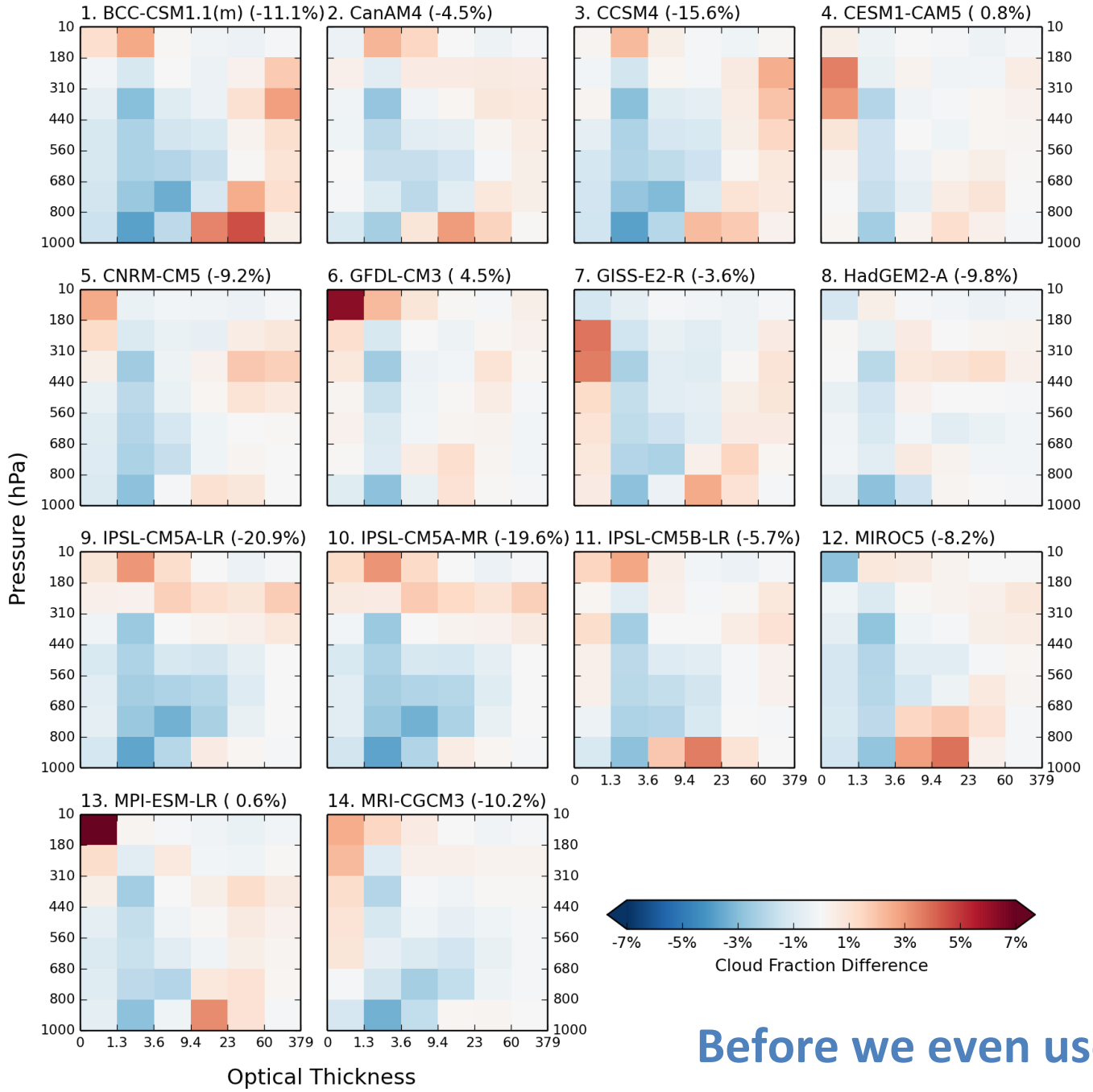
Motivation

- Traditional GCM cloud evaluation sometimes simplistic
- We can now do better with simulators (e.g., COSP)
- Perhaps a “cloud type”-based evaluation is in order?
- But in areas ~$(100\text{-}300\text{km})^2$ multiple cloud types may exist
- Therefore it may make more sense to talk about cloud “mixtures”, the most dominant of which we call “cloud regimes”
- One way of obtaining Cloud Regimes is clustering analysis applied to cloud property co-variations, like the ISCCP “weather states”.

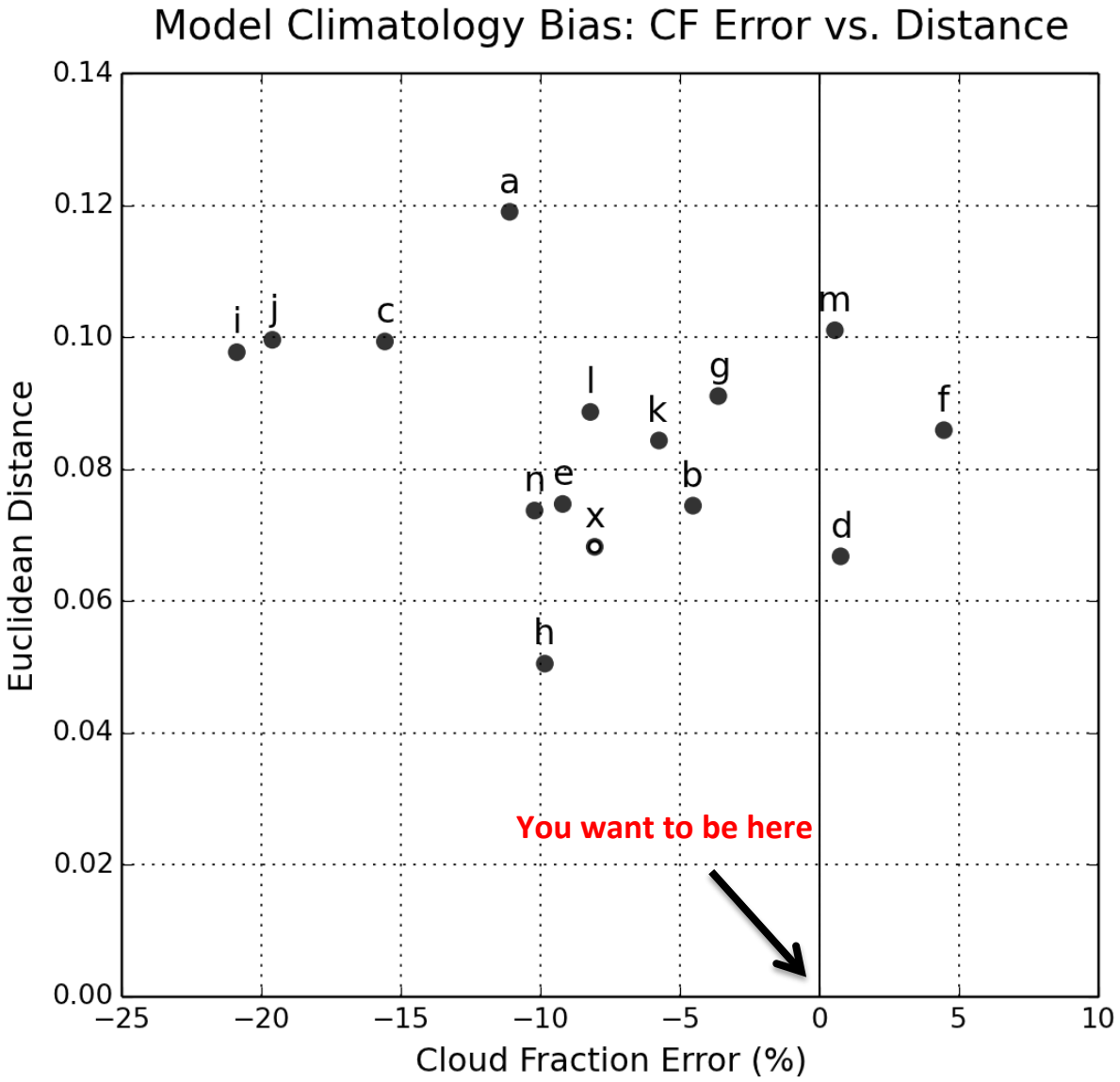
Dataset and methodology

- Regime-based model evaluation; only daytime
- Reference Cloud Regimes (CRs) are the ISCCP Global Weather States of Tselioudis et al. (2013); See Jin et al. poster for an alternate (simpler) set also from ISCCP.
- CMIP5 (CFMIP2) AMIP runs: 14 AGCMs with ISCCP simulator output, specifically joint (2D) CTP-COT histograms
- Convert all data to common 2.5° grid; only multi-annual means
- "Force" each AGCM 2D histogram to closest (based on Euclidean distance) ISCCP CR
- Mean of all AGCM 2D histos belonging to an ISCCP CR forms the model's own "version" (centroid) of that CR
- Various metrics developed to examine how realistic the AGCM CRs are compared to ISCCP
- We also examine multi-model mean



Before we even use CRs (1)

Before we even use CRs (2)



a. BCC-CSM1.1(m)

b. CanAM4

c. CCSM4

d. CESM1-CAM5

e. CNRM-CM5

f. GFDL-CM3

g. GISS-E2-R

h. HadGEM2-A

i. IPSL-CM5A-LR

j. IPSL-CM5A-MR

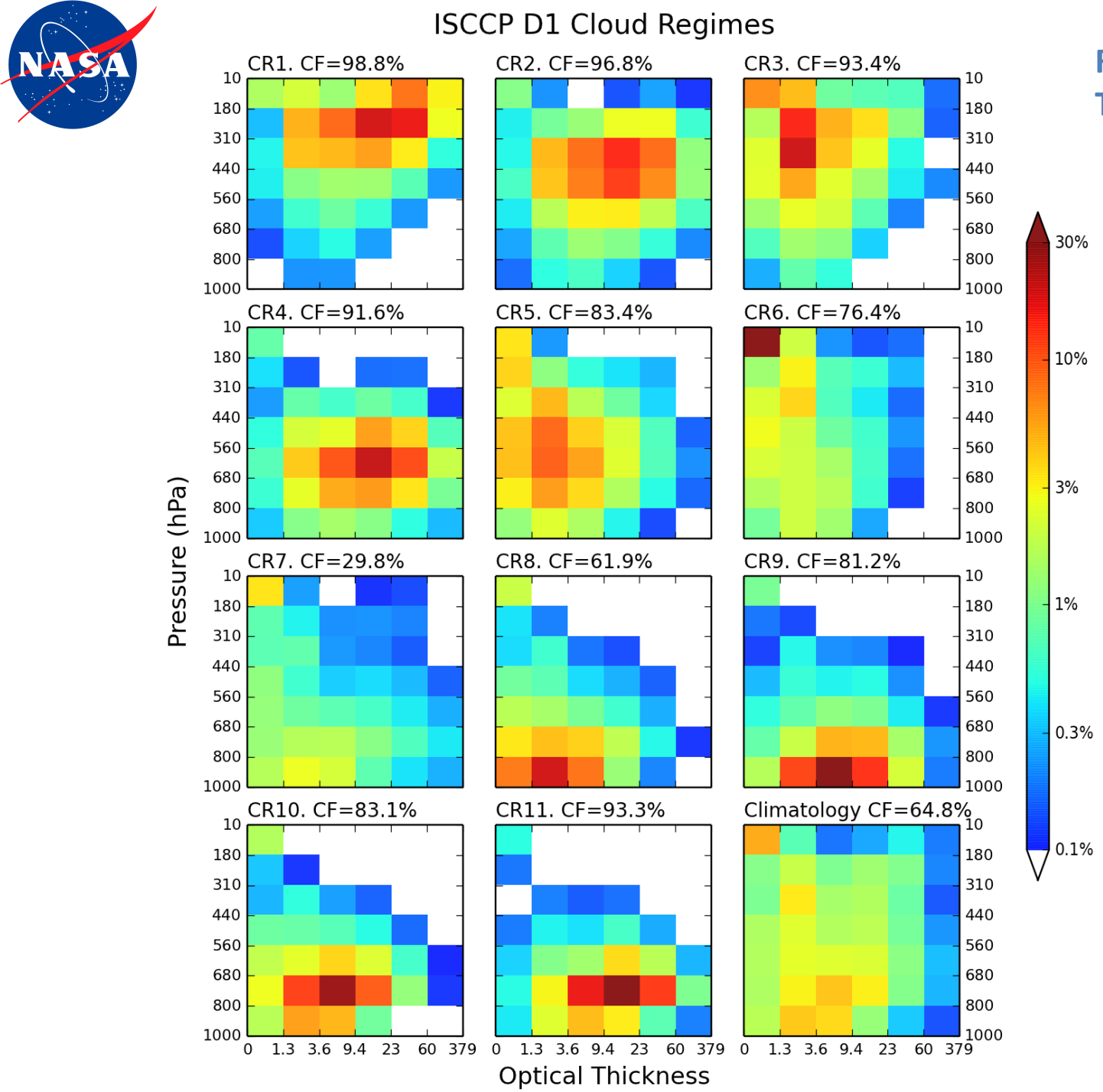
k. IPSL-CM5B-LR

l. MIROC5

m. MPI-ESM-LR

n. MRI-CGCM3

x. CMIP5 Mean



Reference dataset
Tselioudis et al. 2013

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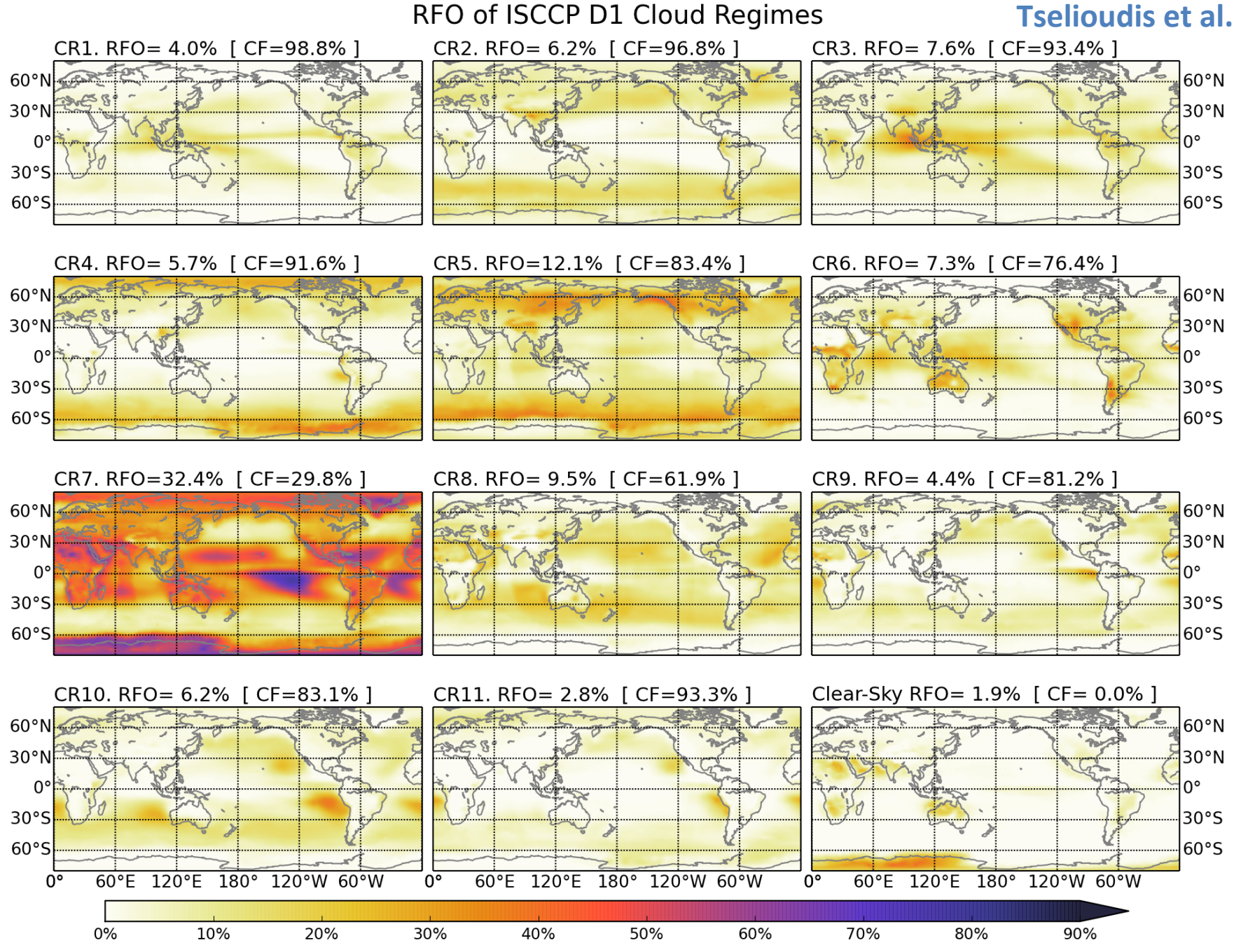
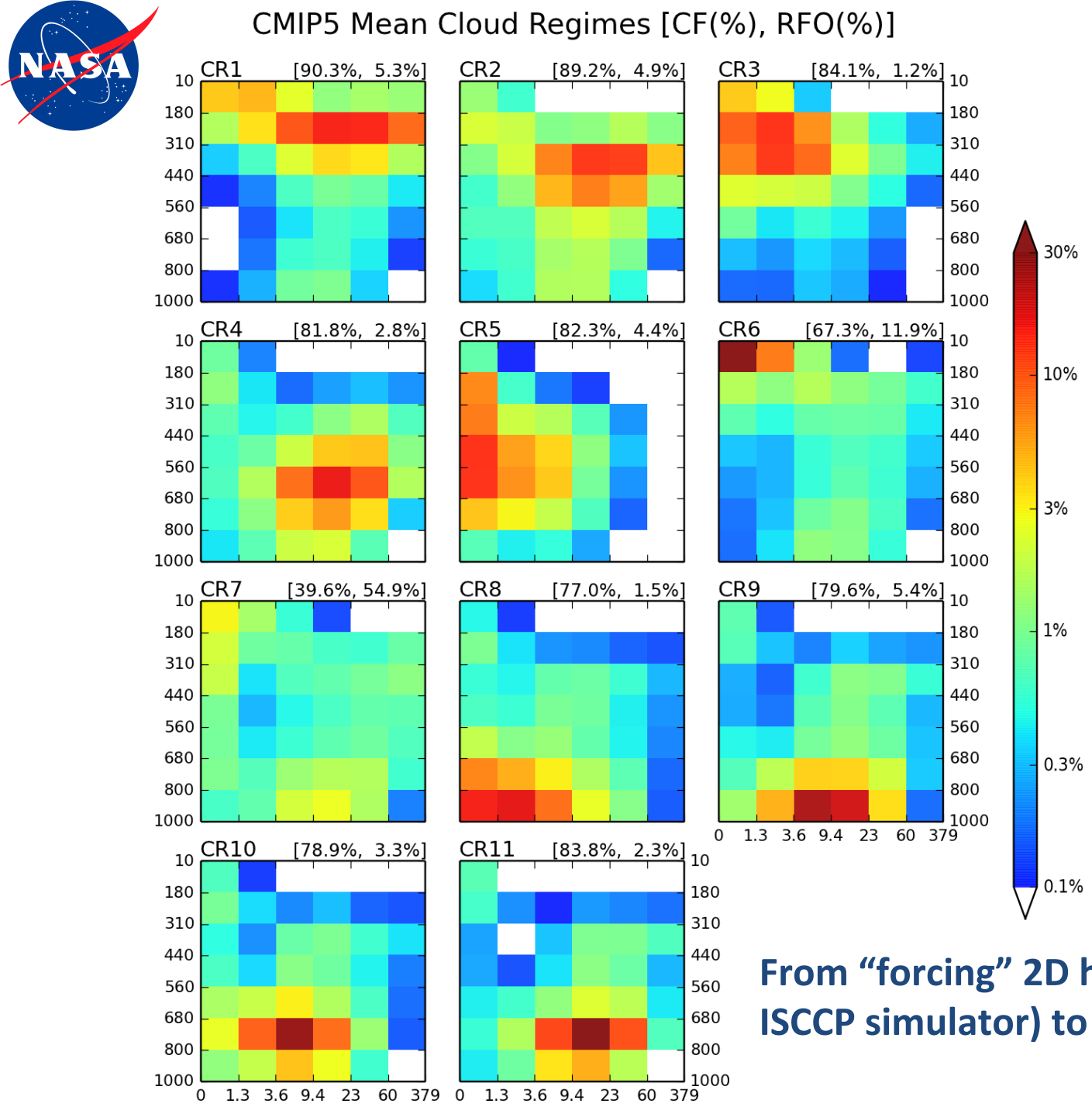
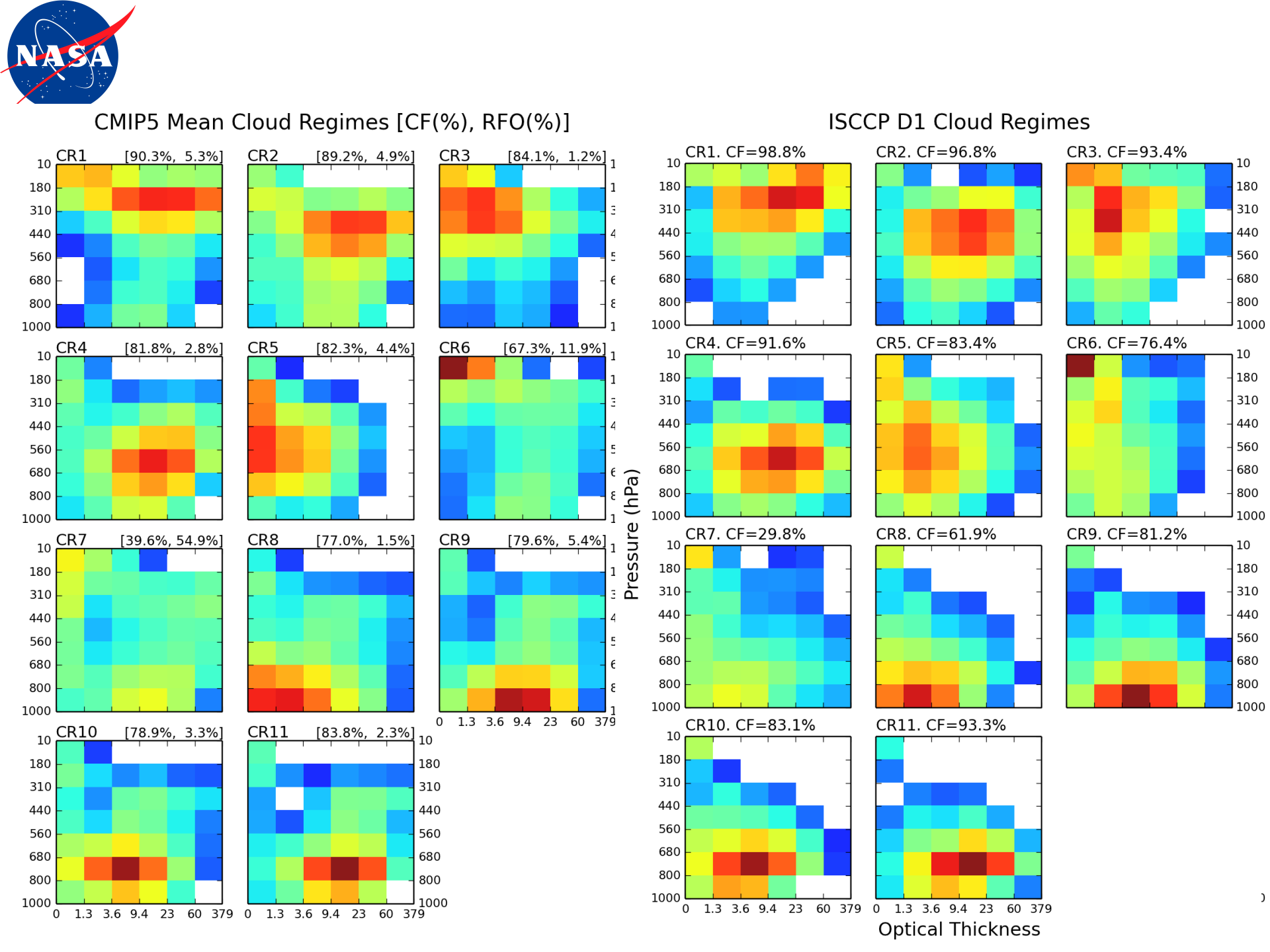
Tselioudis et al. 2013



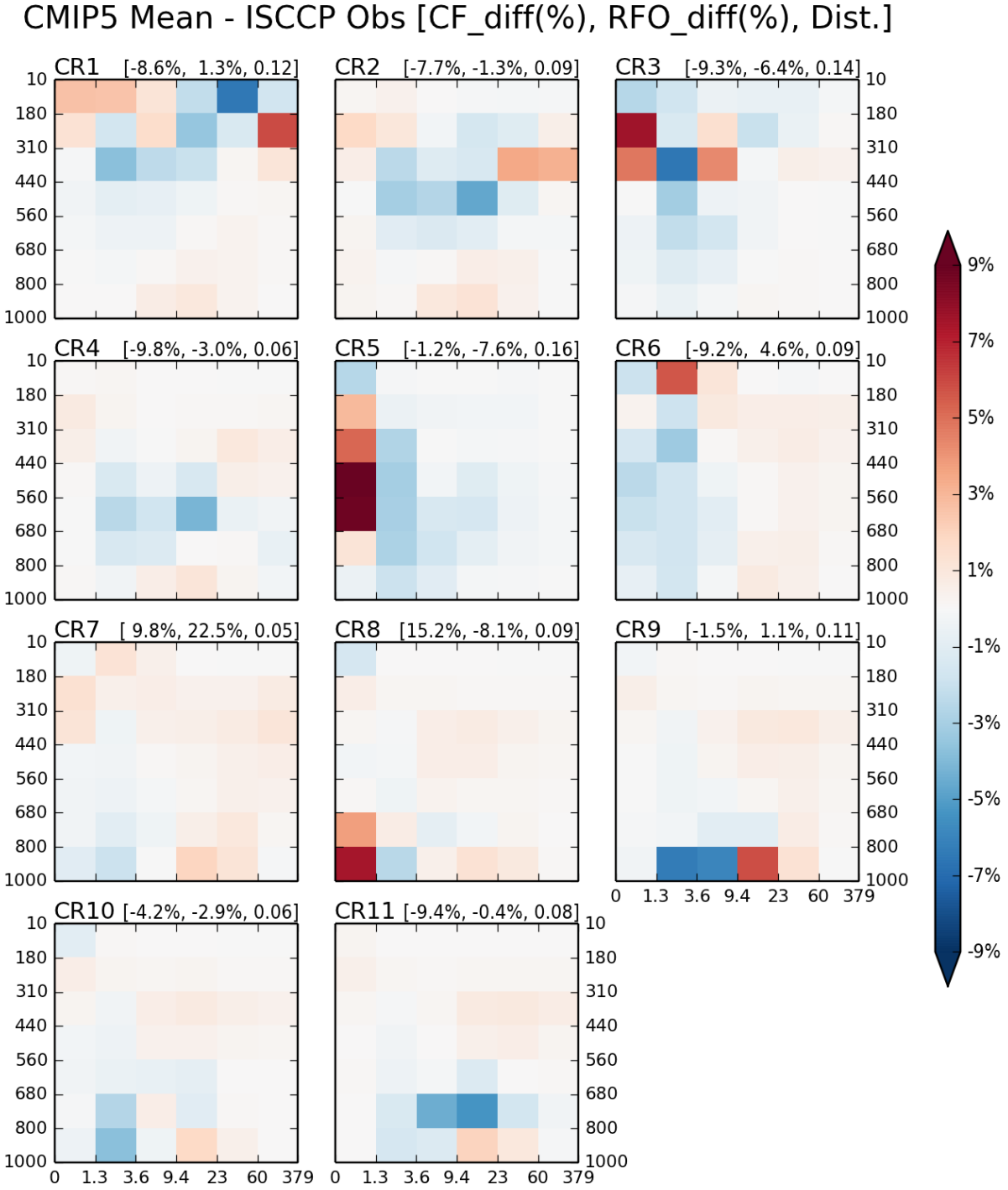


From "forcing" 2D histos of CMIP5 (from ISCCP simulator) to the closest ISCCP CR

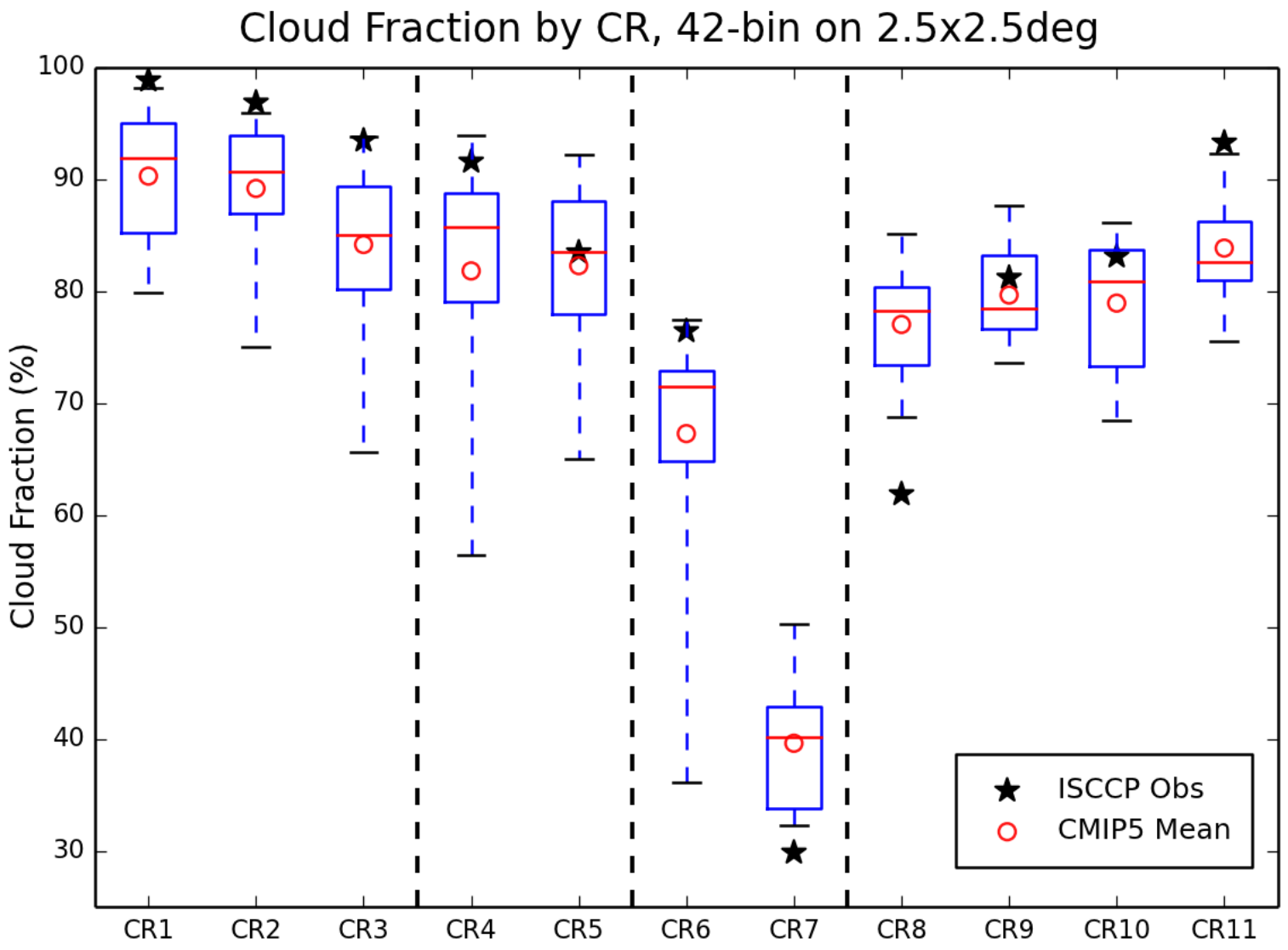

CMIP5 Mean Cloud Regimes [CF(%), RFO(%)]
CR1 [90.3%, 5.3%]
CR2 [89.2%, 4.9%]
CR3 [84.1%, 1.2%]
CR4 [81.8%, 2.8%]
CR5 [82.3%, 4.4%]
CR6 [67.3%, 11.9%]
CR7 [39.6%, 54.9%]
CR8 [77.0%, 1.5%]
CR9 [79.6%, 5.4%]
CR10 [78.9%, 3.3%]
CR11 [83.8%, 2.3%]
ISCCP D1 Cloud Regimes
CR1. CF=98.8%
CR2. CF=96.8%
CR3. CF=93.4%
CR4. CF=91.6%
CR5. CF=83.4%
CR6. CF=76.4%
CR7. CF=29.8%
CR8. CF=61.9%
CR9. CF=81.2%
CR10. CF=83.1%
CR11. CF=93.3%
Pressure (hPa)
10 180 310 440 560 680 800 1000
0 1.3 3.6 9.4 23 60 379
Optical Thickness

Performance of multi-model CMIP5 mean by CR

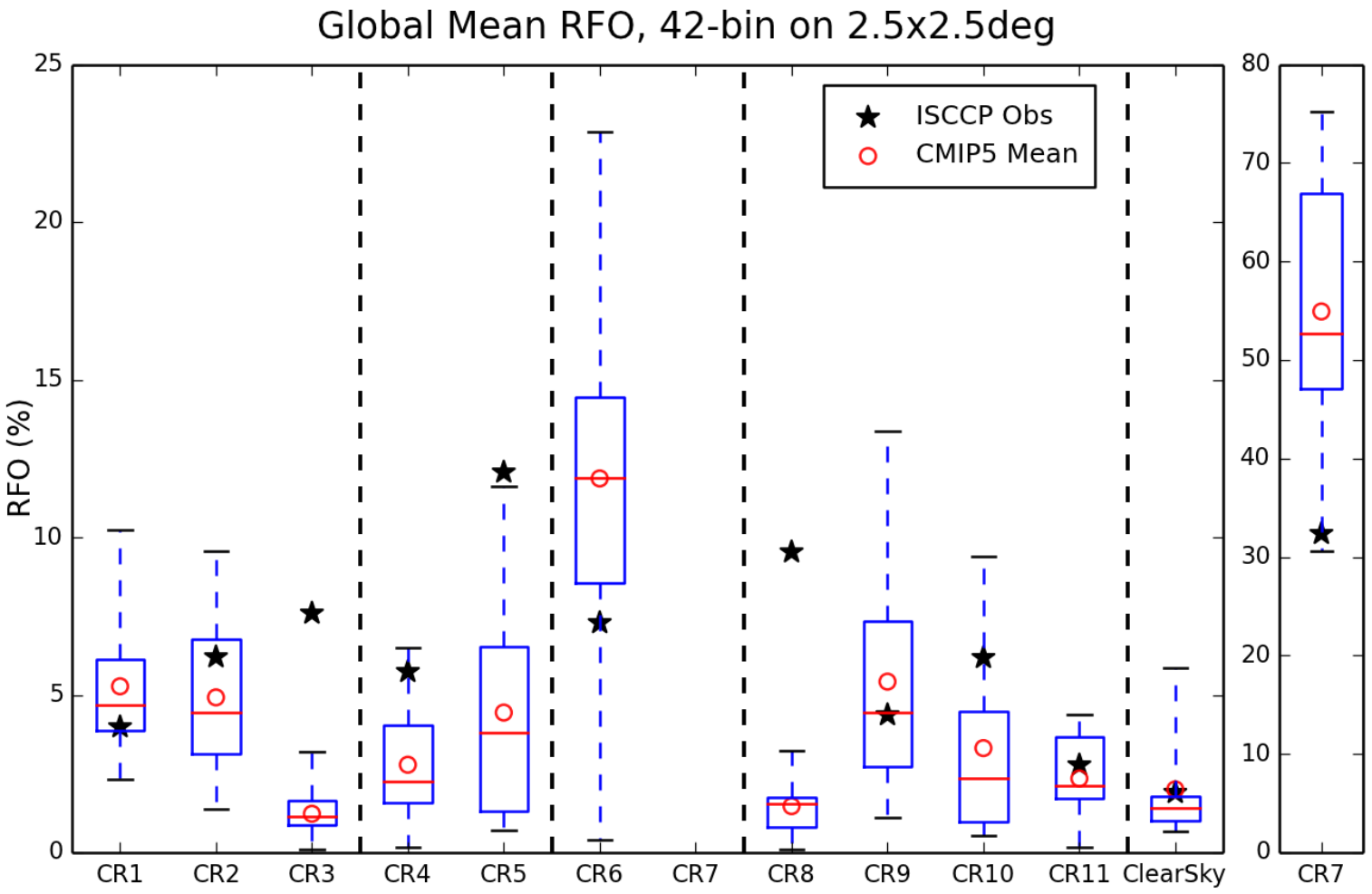
$$D_k = \sqrt{\sum_{i=1}^{42} \left(x_{i,k} - y_{i,k} \right)^2}$$



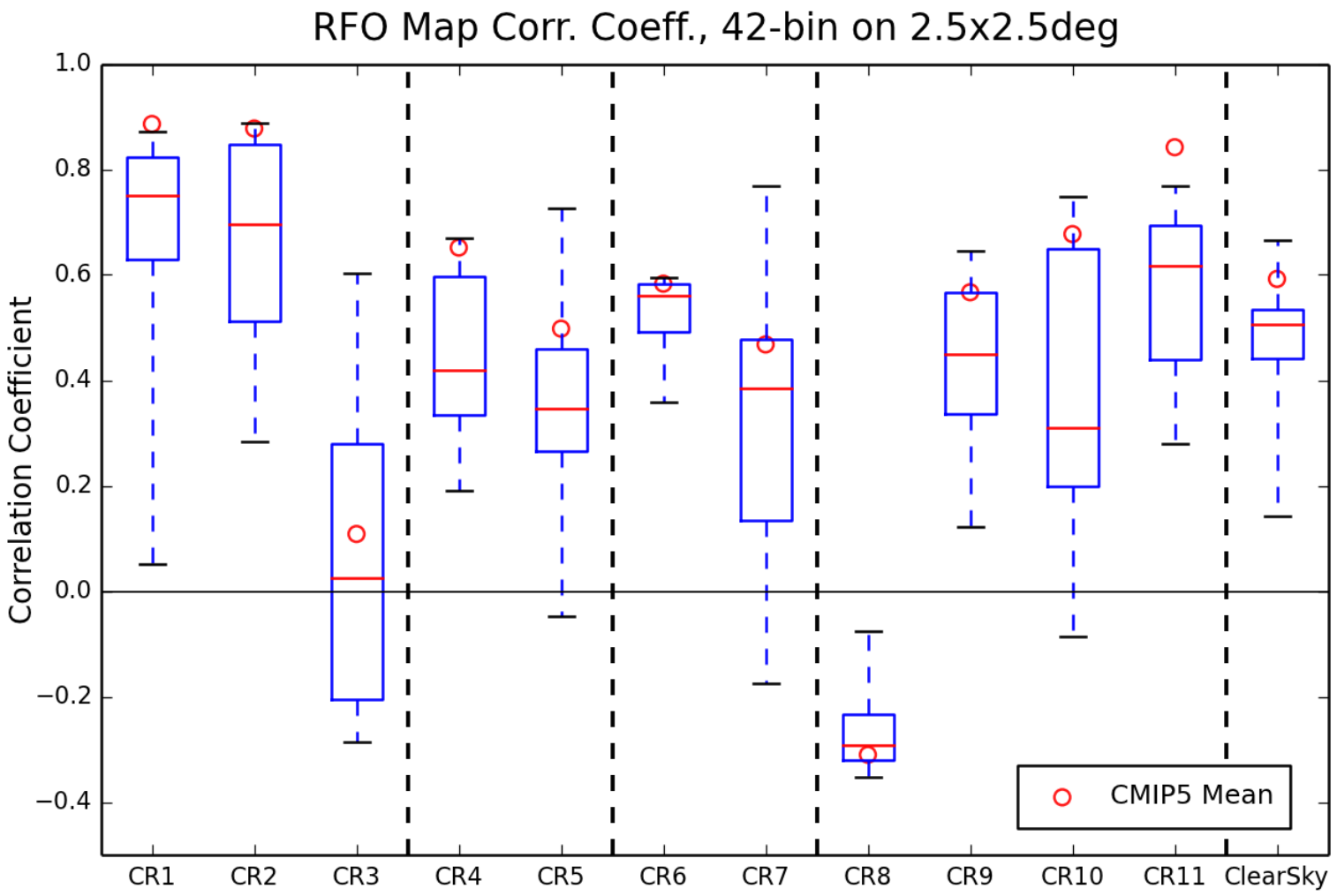
CR Cloud Fraction statistics



CR global RFO statistics

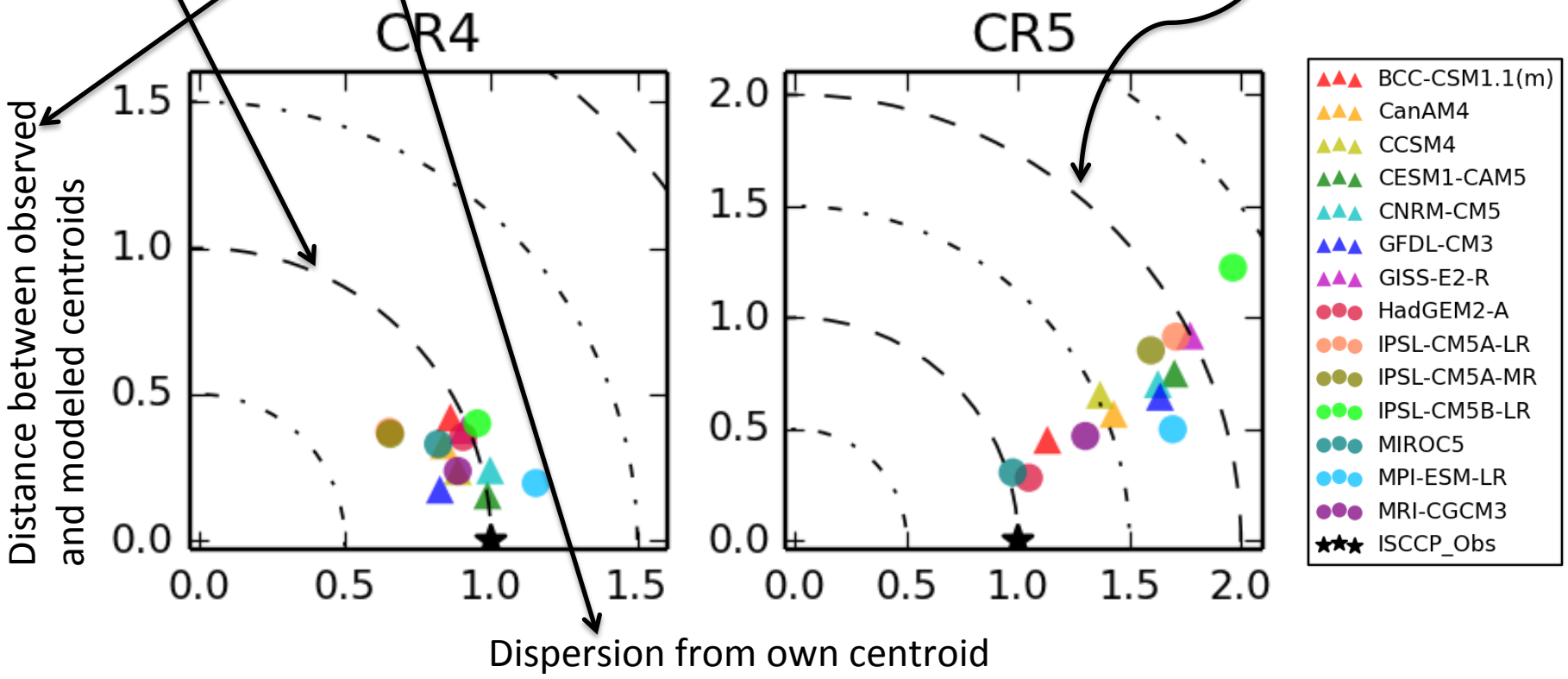


CR RFO map correlation statistics

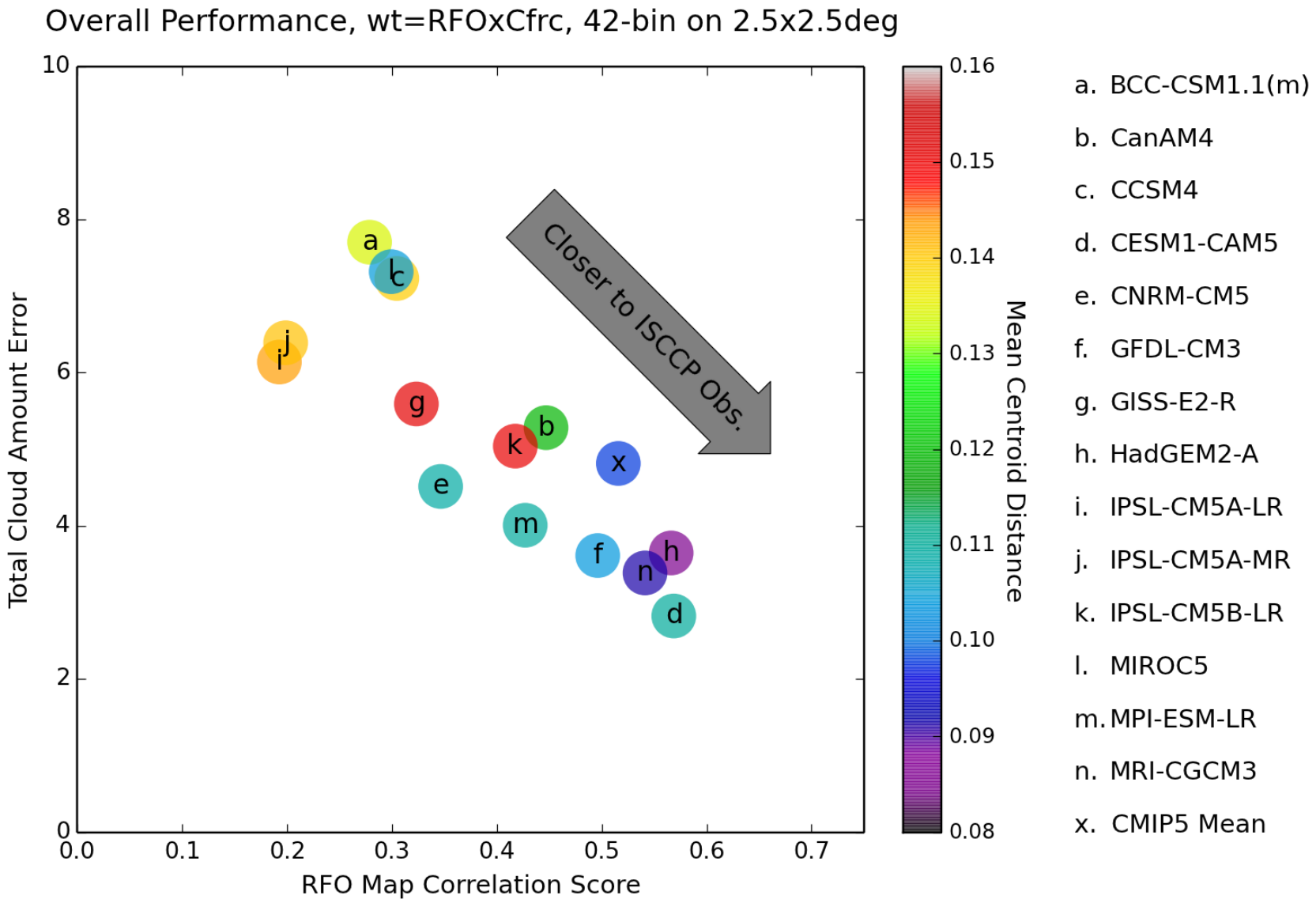


Euclidean Distance relationship

$$\overline{DRC_k^2} = \overline{D_k^2} + \overline{DOC_k^2}$$



Averaging across CRs



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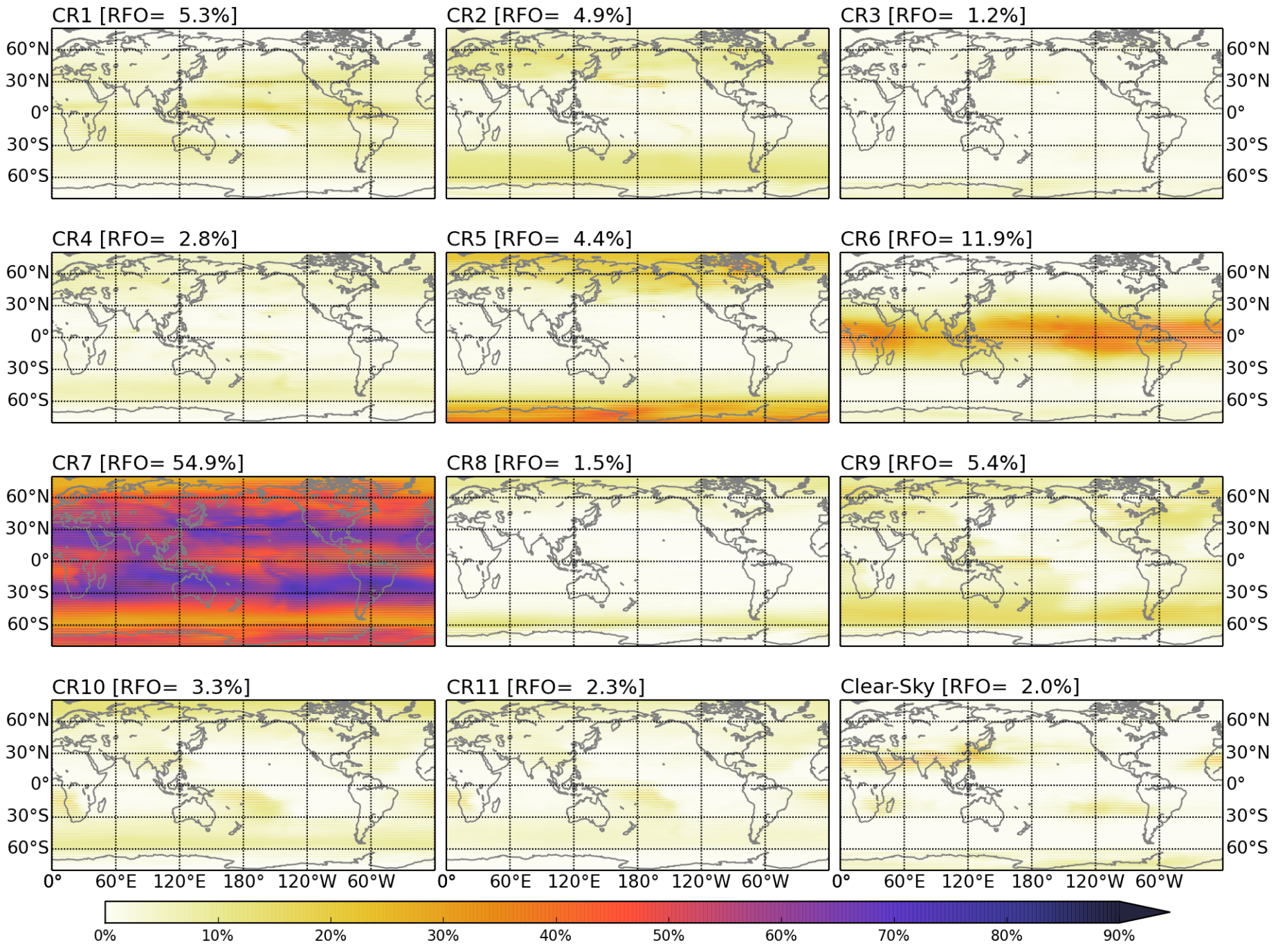
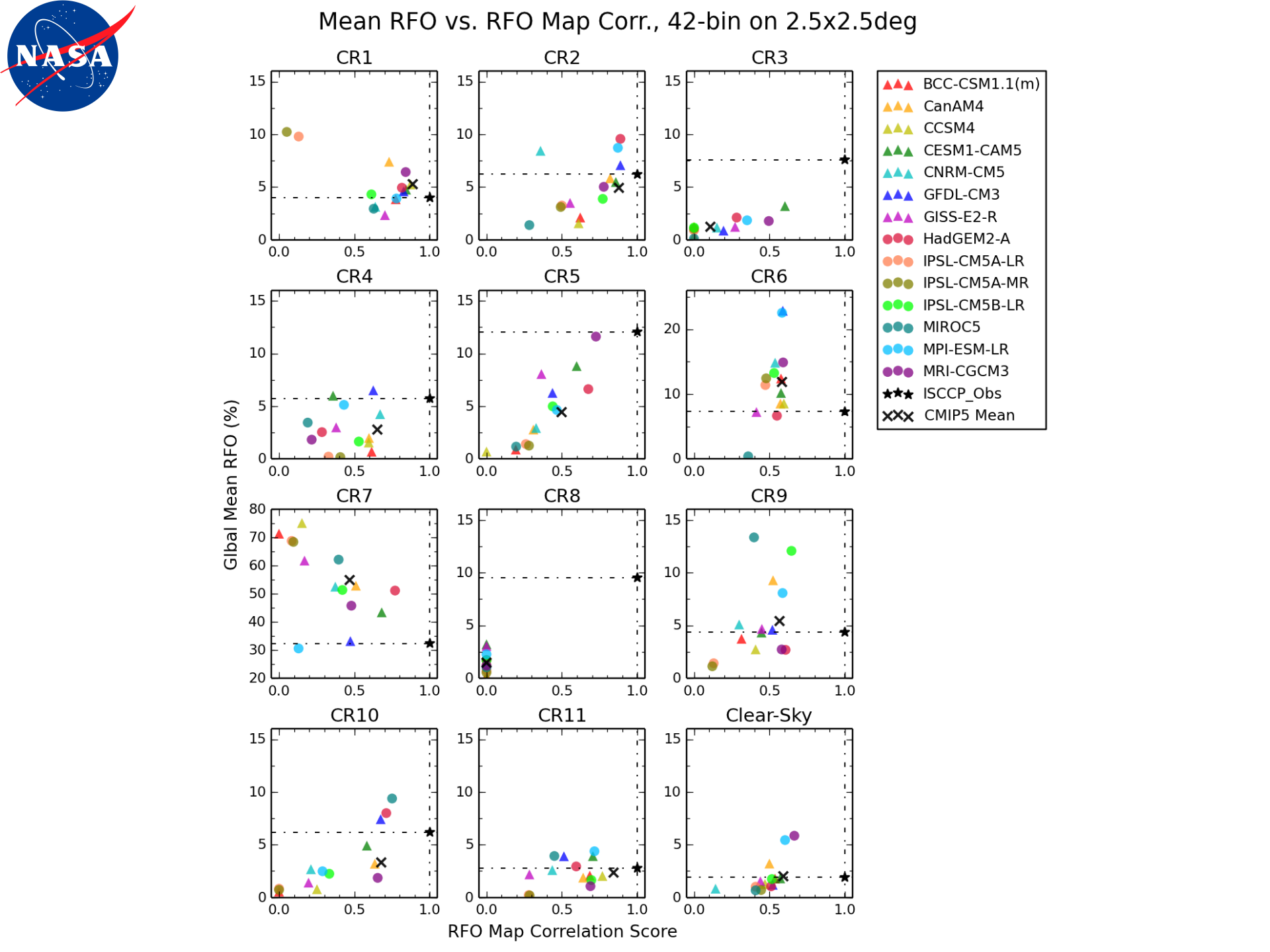
k. IPSL-CM5B-LR
l. MIROC5
m. MPI-ESM-LR
n. MRI-CGCM3
x. CMIP5 Mean

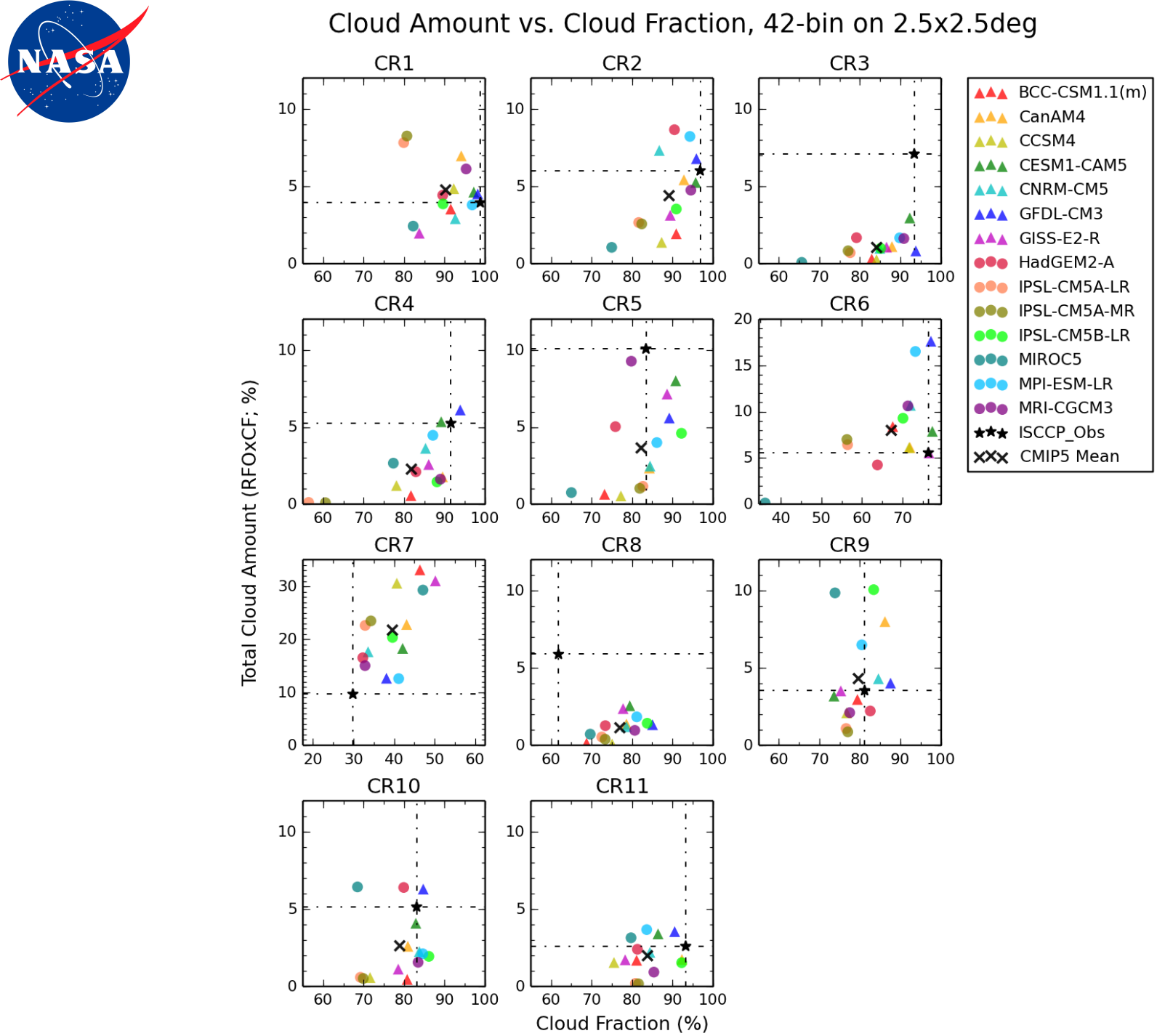
Take home messages

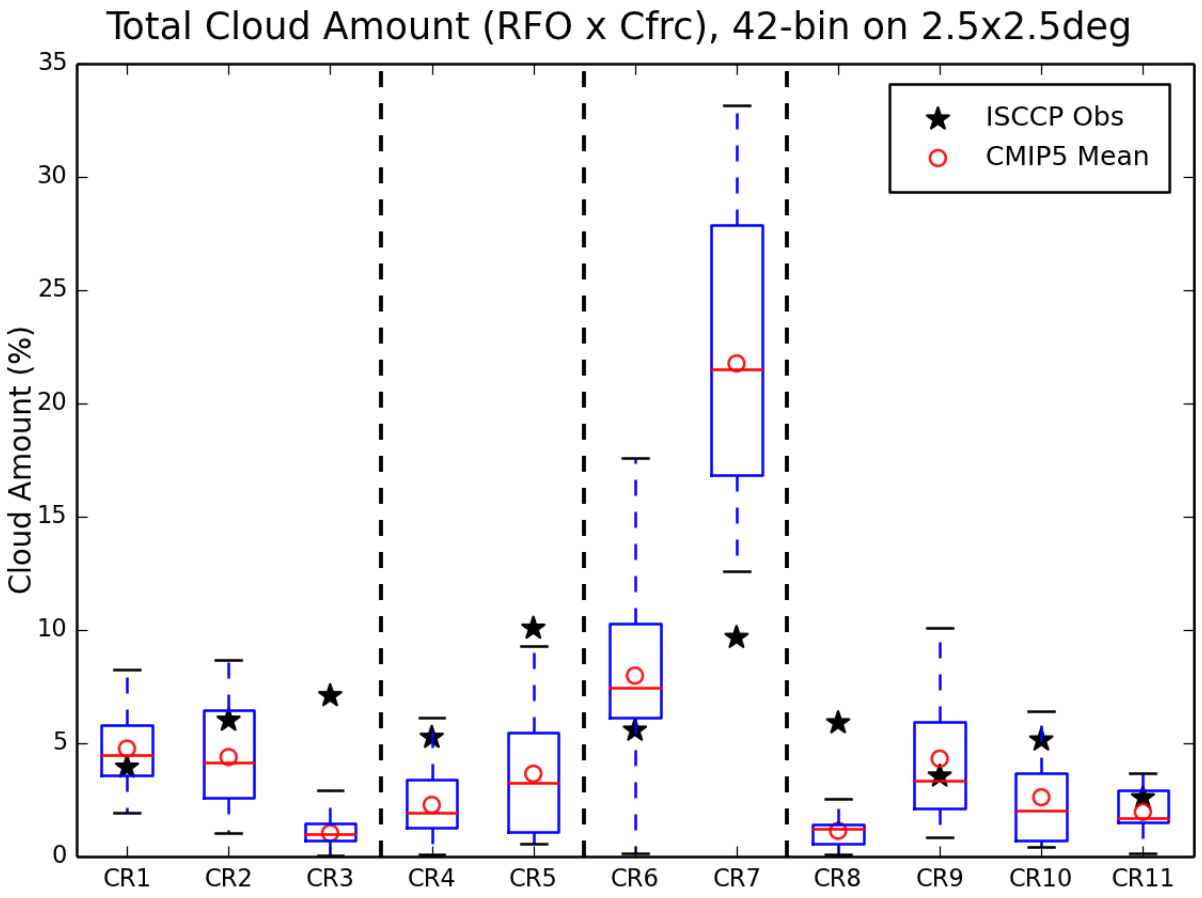
- ISCCP simulator output allows a regime-based evaluation of CMIP5 AGCM cloudiness
- New evaluation framework developed with several metrics
- We now know how close model CRs compare to ISCCP in terms of appearance, global frequency, location
- "Too few, too thick" confirmed with this approach as well
  - ✧ Too many occurrences of "thin" CRs and too few "thick" CRs
- But CRs dominated by thick clouds still some of the best
- Multi-model mean not outperforming best models
- Next, consider MODIS global regimes(?)

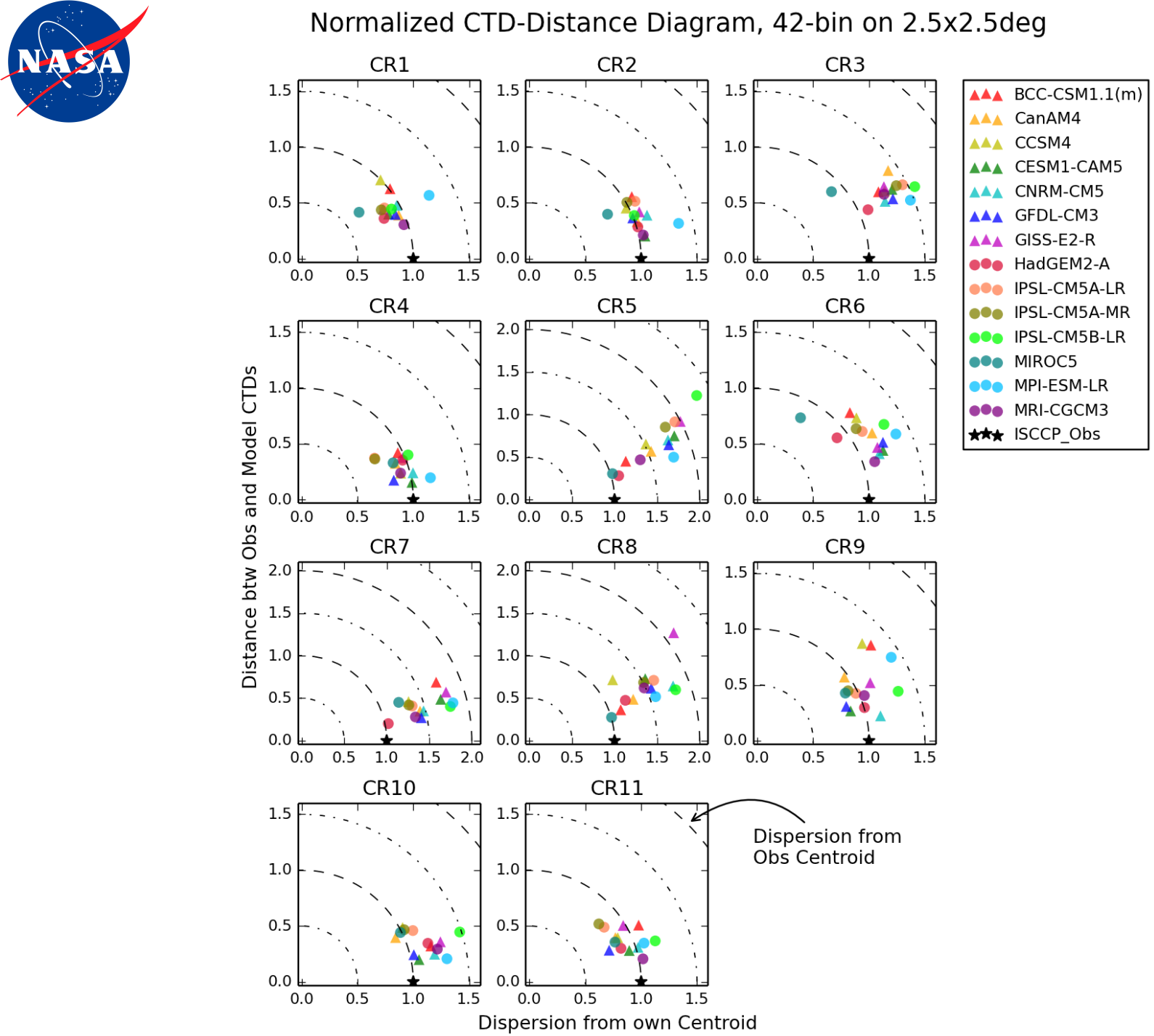
Additional slides

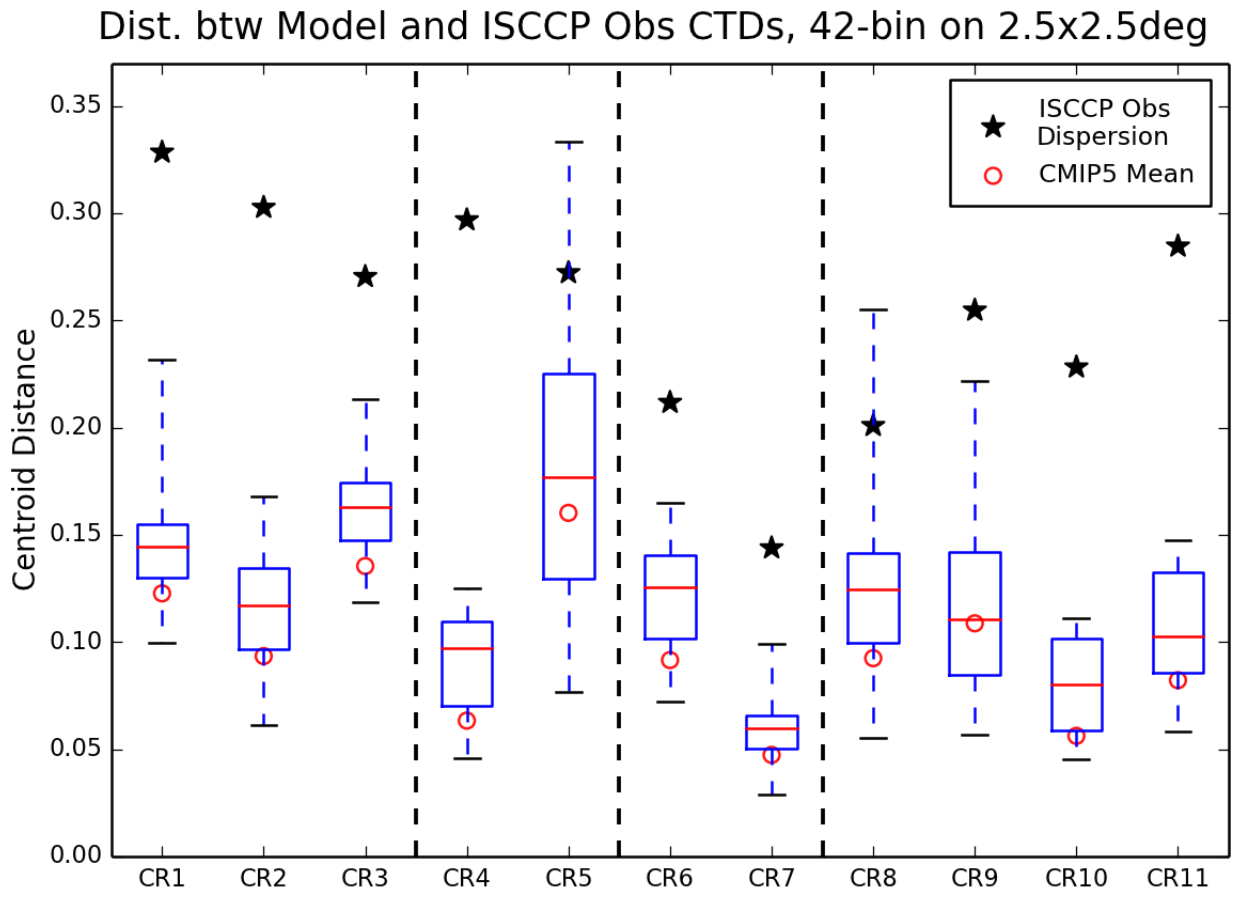

Multi-Model Mean of Cloud Regime RFO
CR1 [RFO= 5.3%]
CR2 [RFO= 4.9%]
CR3 [RFO= 1.2%]
CR4 [RFO= 2.8%]
CR5 [RFO= 4.4%]
CR6 [RFO= 11.9%]
CR7 [RFO= 54.9%]
CR8 [RFO= 1.5%]
CR9 [RFO= 5.4%]
CR10 [RFO= 3.3%]
CR11 [RFO= 2.3%]
Clear-Sky [RFO= 2.0%]
60°N
30°N
0°
30°S
60°S
0° 60°E 120°E 180° 120°W 60°W
0% 10% 20% 30% 40% 50% 60% 70% 80% 90%

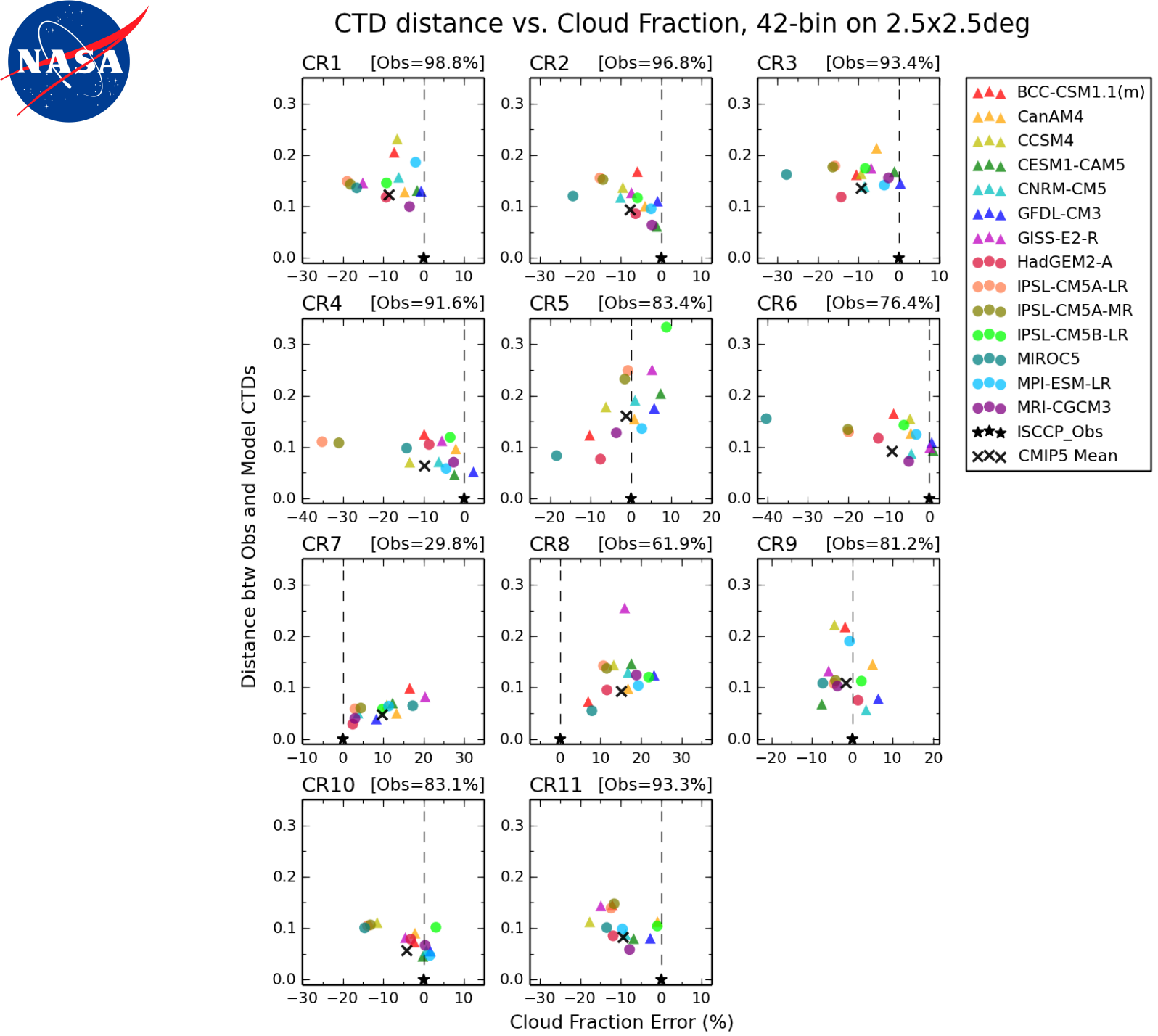

Mean RFO vs. RFO Map Corr., 42-bin on 2.5x2.5deg
CR1
CR2
CR3
CR4
CR5
CR6
CR7
CR8
CR9
CR10
CR11
Clear-Sky
Glbal Mean RFO (%)
RFO Map Correlation Score
BCC-CSM1.1(m)
CanAM4
CCSM4
CESM1-CAM5
CNRM-CM5
GFDL-CM3
GISS-E2-R
HadGEM2-A
IPSL-CM5A-LR
IPSL-CM5A-MR
IPSL-CM5B-LR
MIROC5
MPI-ESM-LR
MRI-CGCM3
ISCCP_Obs
CMIP5 Mean


Cloud Amount vs. Cloud Fraction, 42-bin on 2.5x2.5deg
CR1
CR2
CR3
CR4
CR5
CR6
CR7
CR8
CR9
CR10
CR11
Total Cloud Amount (RFOxCF; %)
Cloud Fraction (%)
BCC-CSM1.1(m)
CanAM4
CCSM4
CESM1-CAM5
CNRM-CM5
GFDL-CM3
GISS-E2-R
HadGEM2-A
IPSL-CM5A-LR
IPSL-CM5A-MR
IPSL-CM5B-LR
MIROC5
MPI-ESM-LR
MRI-CGCM3
ISCCP_Obs
CMIP5 Mean


Total Cloud Amount (RFO x Cfrc), 42-bin on 2.5x2.5deg
Cloud Amount (%)
0
5
10
15
20
25
30
35
CR1
CR2
CR3
CR4
CR5
CR6
CR7
CR8
CR9
CR10
CR11
ISCCP Obs
CMIP5 Mean


Normalized CTD-Distance Diagram, 42-bin on 2.5x2.5deg
CR1
CR2
CR3
CR4
CR5
CR6
CR7
CR8
CR9
CR10
CR11
Distance btw Obs and Model CTDs
Dispersion from own Centroid
Dispersion from
Obs Centroid
BCC-CSM1.1(m)
CanAM4
CCSM4
CESM1-CAM5
CNRM-CM5
GFDL-CM3
GISS-E2-R
HadGEM2-A
IPSL-CM5A-LR
IPSL-CM5A-MR
IPSL-CM5B-LR
MIROC5
MPI-ESM-LR
MRI-CGCM3
ISCCP_Obs


Dist. btw Model and ISCCP Obs CTDs, 42-bin on 2.5x2.5deg
Centroid Distance
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
CR1
CR2
CR3
CR4
CR5
CR6
CR7
CR8
CR9
CR10
CR11
ISCCP Obs Dispersion
CMIP5 Mean


CTD distance vs. Cloud Fraction, 42-bin on 2.5x2.5deg
CR1 [Obs=98.8%]
CR2 [Obs=96.8%]
CR3 [Obs=93.4%]
CR4 [Obs=91.6%]
CR5 [Obs=83.4%]
CR6 [Obs=76.4%]
CR7 [Obs=29.8%]
CR8 [Obs=61.9%]
CR9 [Obs=81.2%]
CR10 [Obs=83.1%]
CR11 [Obs=93.3%]
Distance btw Obs and Model CTDs
Cloud Fraction Error (%)
BCC-CSM1.1(m)
CanAM4
CCSM4
CESM1-CAM5
CNRM-CM5
GFDL-CM3
GISS-E2-R
HadGEM2-A
IPSL-CM5A-LR
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CMIP5 Mean