An Assessment of Cloud Properties Simulated by NICAM Using ISCCP, CALIPSO and CloudSat Satellite Simulators

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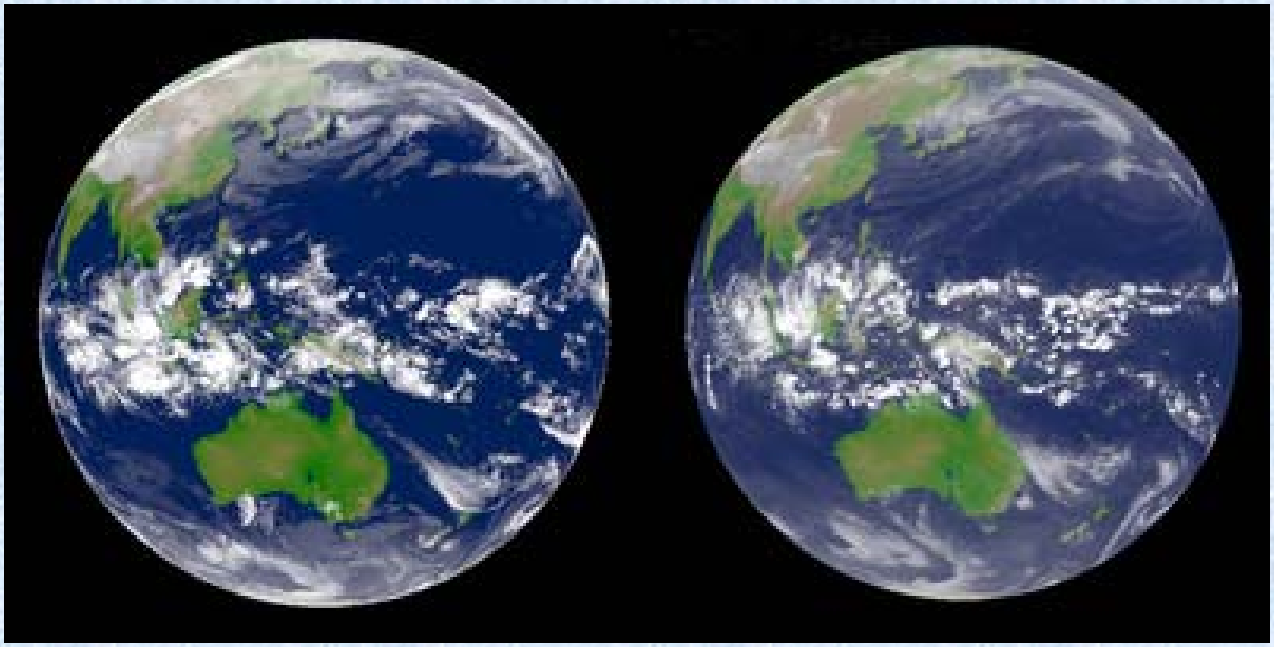
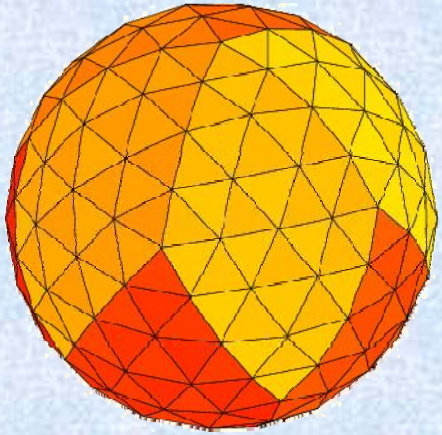
What is NICAM

- Nonhydrostatic ICosahedral Atmospheric Model for Global Cloud-Resolving Simulations

  Tomita and Satoh, (2005); Satoh et al. (2008)



MTSAT-1R IR vs. NICAM 3.5km OLR
Miura et al. (2007)
Visit http://nicam.jp/ for more beautiful pictures.



NICAM ~ Nonhydrostatic ICosahedral Atmospheric Model

Resolution	Horizontal: 14km (cloud resolving mode) Vertical: 40 layers, 80m~2.9km interval（stretch）up to 40km
Integration	2004.06.01 - 2004.10.31 (5 months)
Cloud Microphysics	NSW6（6-category, 1-moment; Tomita 2007）
Cumulus Convection	No Parameterization
PBL	MYNN2.0（Nakanishi & Niino 2006, Mellor & Yamada
Surface flux	Louis（1979）
Land Process	MATSIRO（Takata et al. 2003）
Ocean	1-layer slab ocean + nudging（τ = 5 days）
Radiation	MSTRNX（Sekiguchi & Nakajima, 2008）
Aerosol	No（but available）

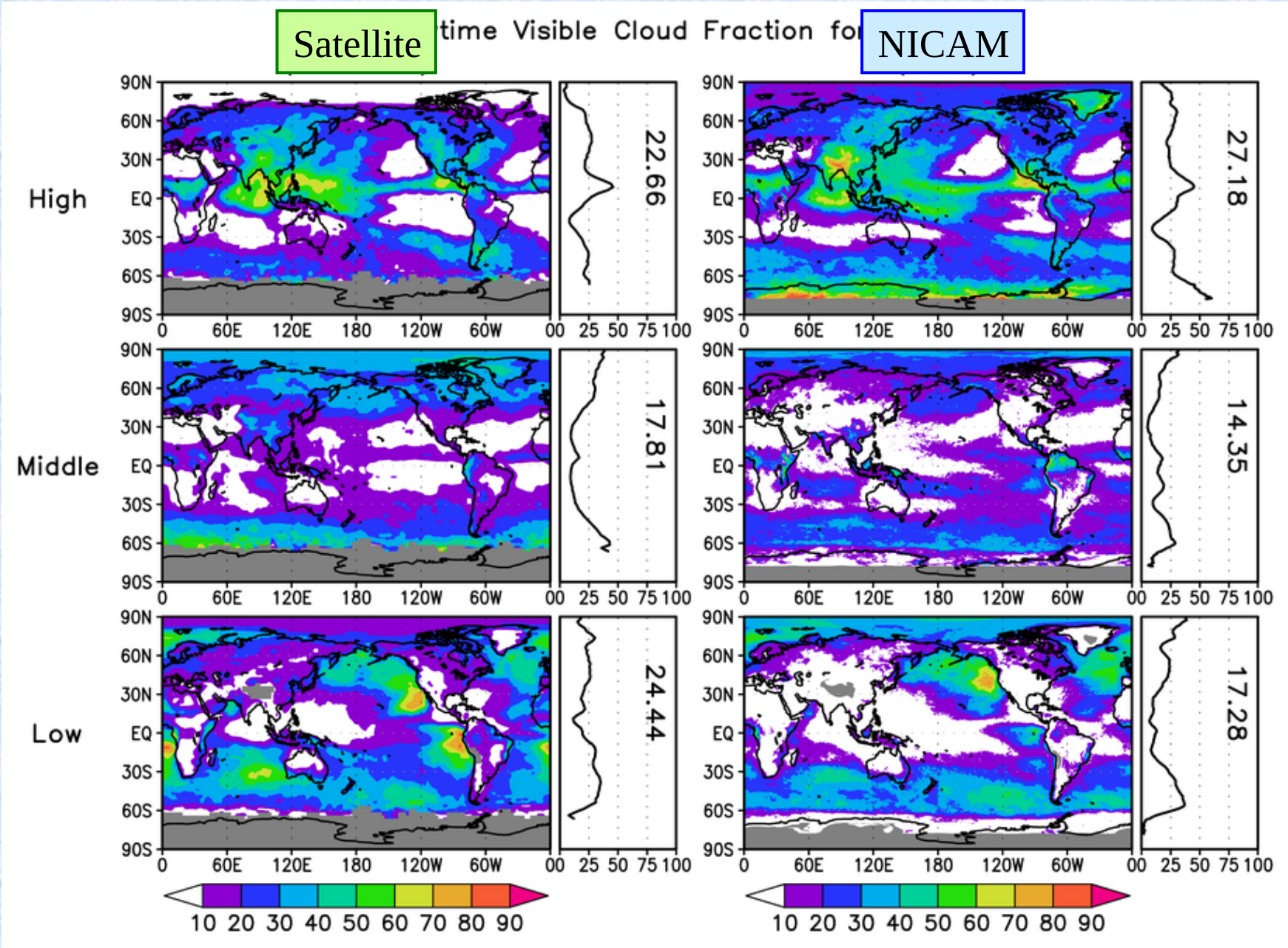
Satellite Simulator & Data

- COSP (CFMIP Observational Simulator Package) v1.3
  - Bodas-Salcedo et al. (2008)
  - ISCCP (Klein and Jakob, 1999; Webb et al. 2001)
  - CALIPSO (Chepfer et al. 2008)
  - CloudSat (Haynes et al. 2007)
  - For CALIPSO and CloudSat, every 4 points in lon. and lat. directions are analyzed to reduce computational costs.
  - Cloud resolving mode

- Satellite Data
  - ISCCP (Rossow and Schiffer, 1999): JJA 2004
  - CALIPSO-GOCCP (Chepfer et al., 2009) : JJA 2006-2008
  - CloudSat (Zhang et al. 2010) : JJA 2006-2010

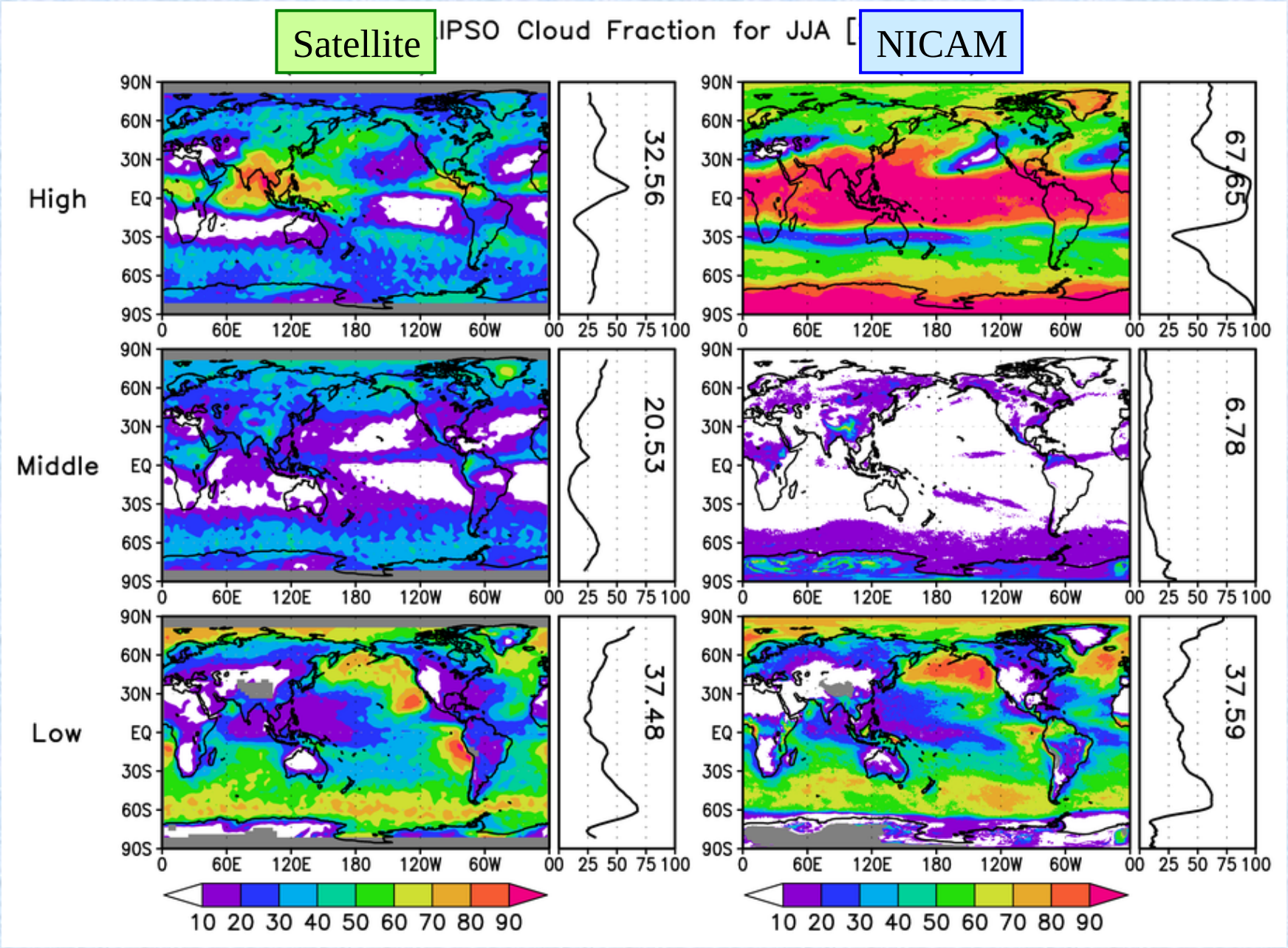
- Def. of cloud fraction follows those used in the satellite data.

ISCCP Daytime Cloud Fraction for JJA



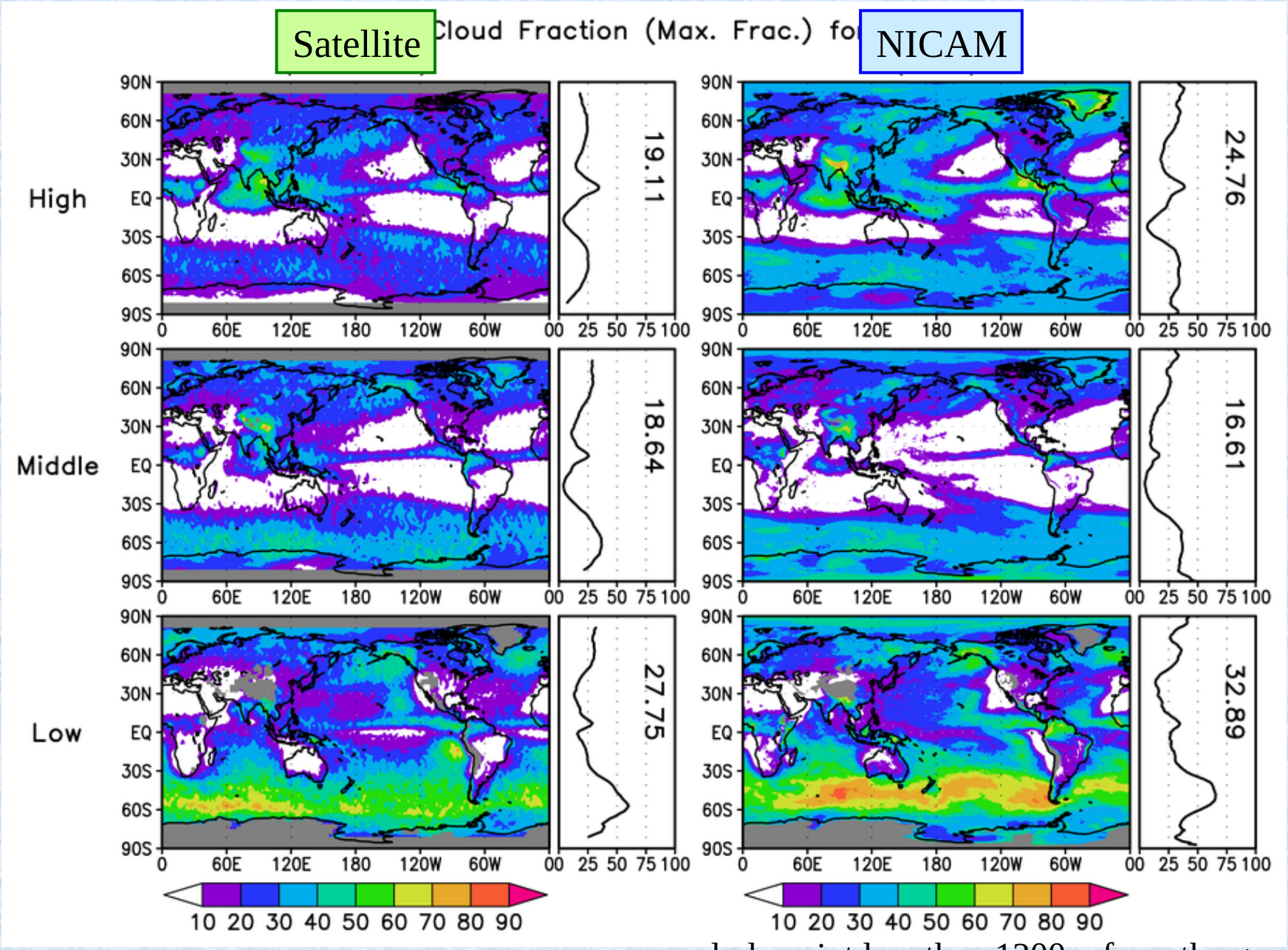
CALIPSO Nighttime Cloud Fraction for JJA

SR > 5



CloudSat Cloud Fraction for JJA

Ze > -30

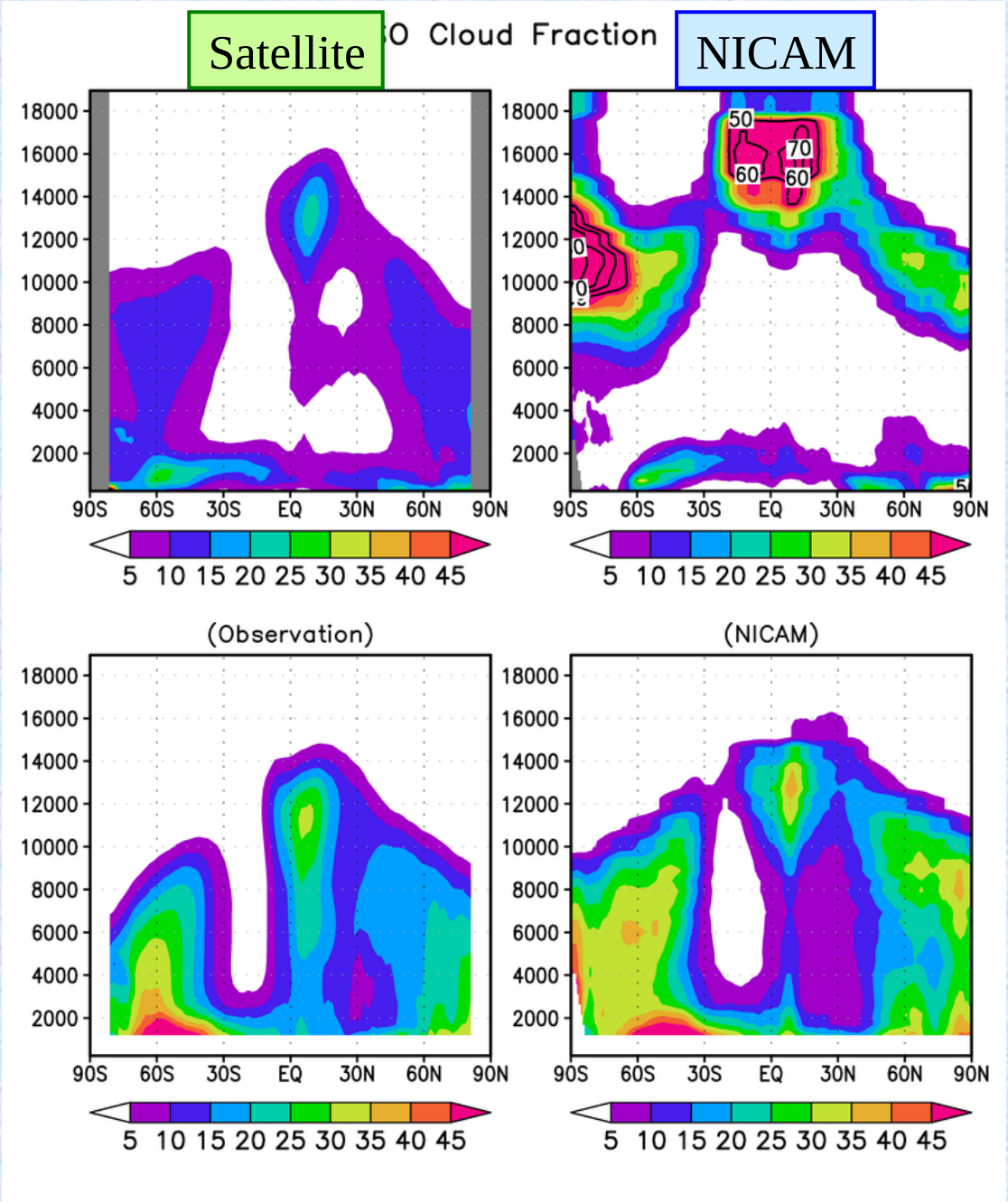


exclude point less than 1200m from the ground

Zonal Mean CALIPSO/CloudSat Cloud Fraction for JJA

CALIPSO

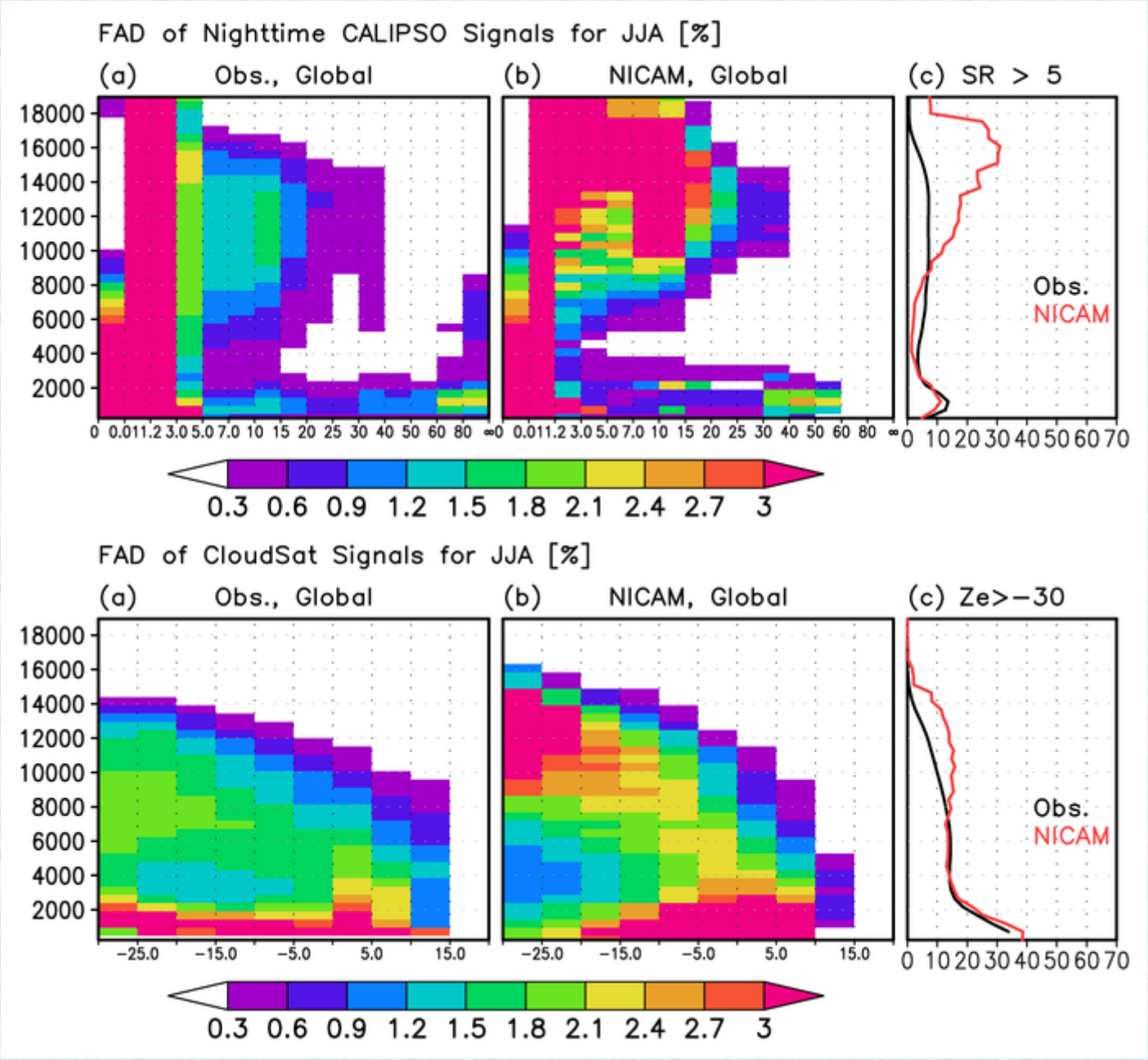
CloudSat



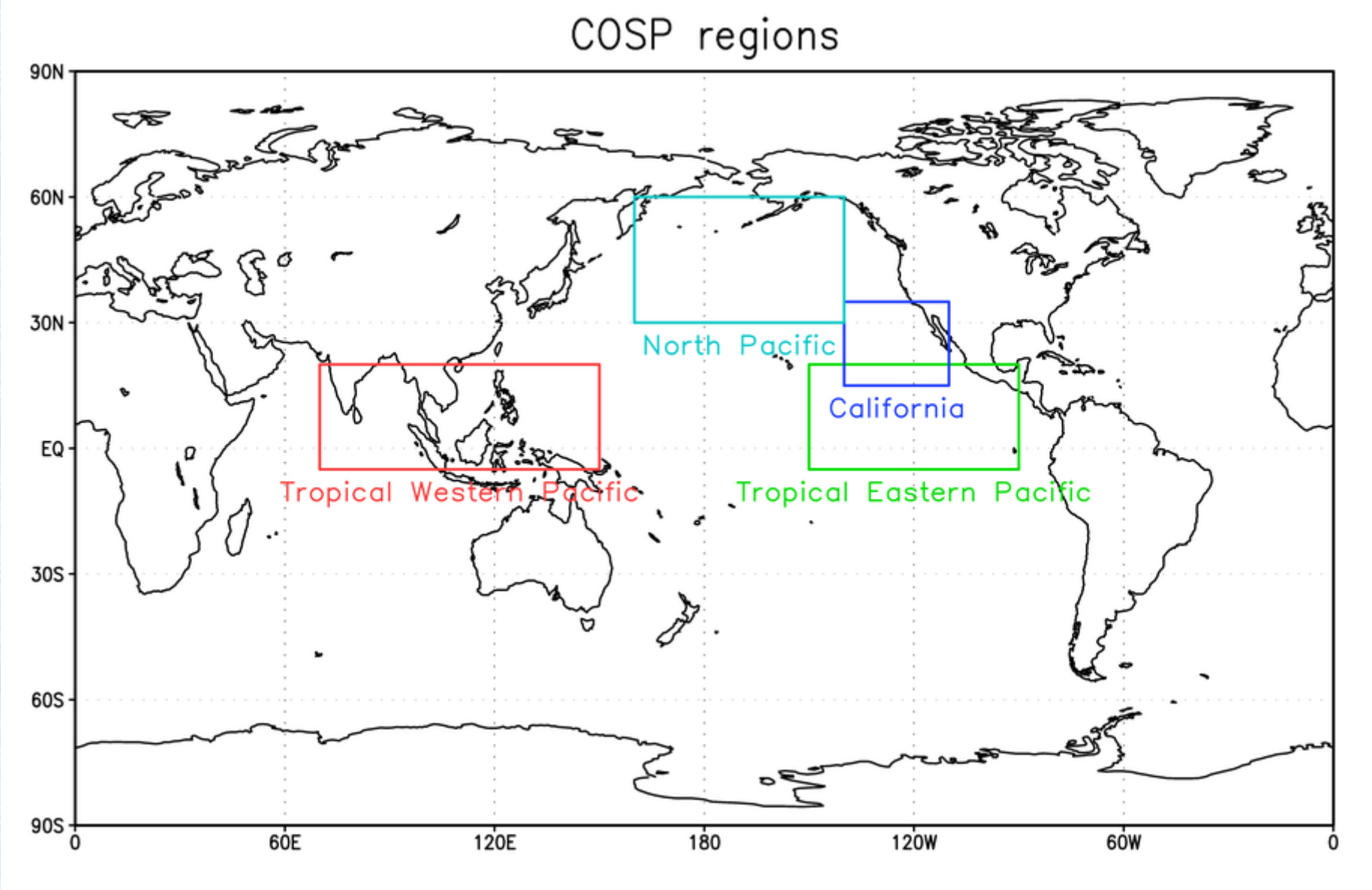
CALIPSO / CloudSat CFAD (Global)

CALIPSO

CloudSat



Targeted Regions

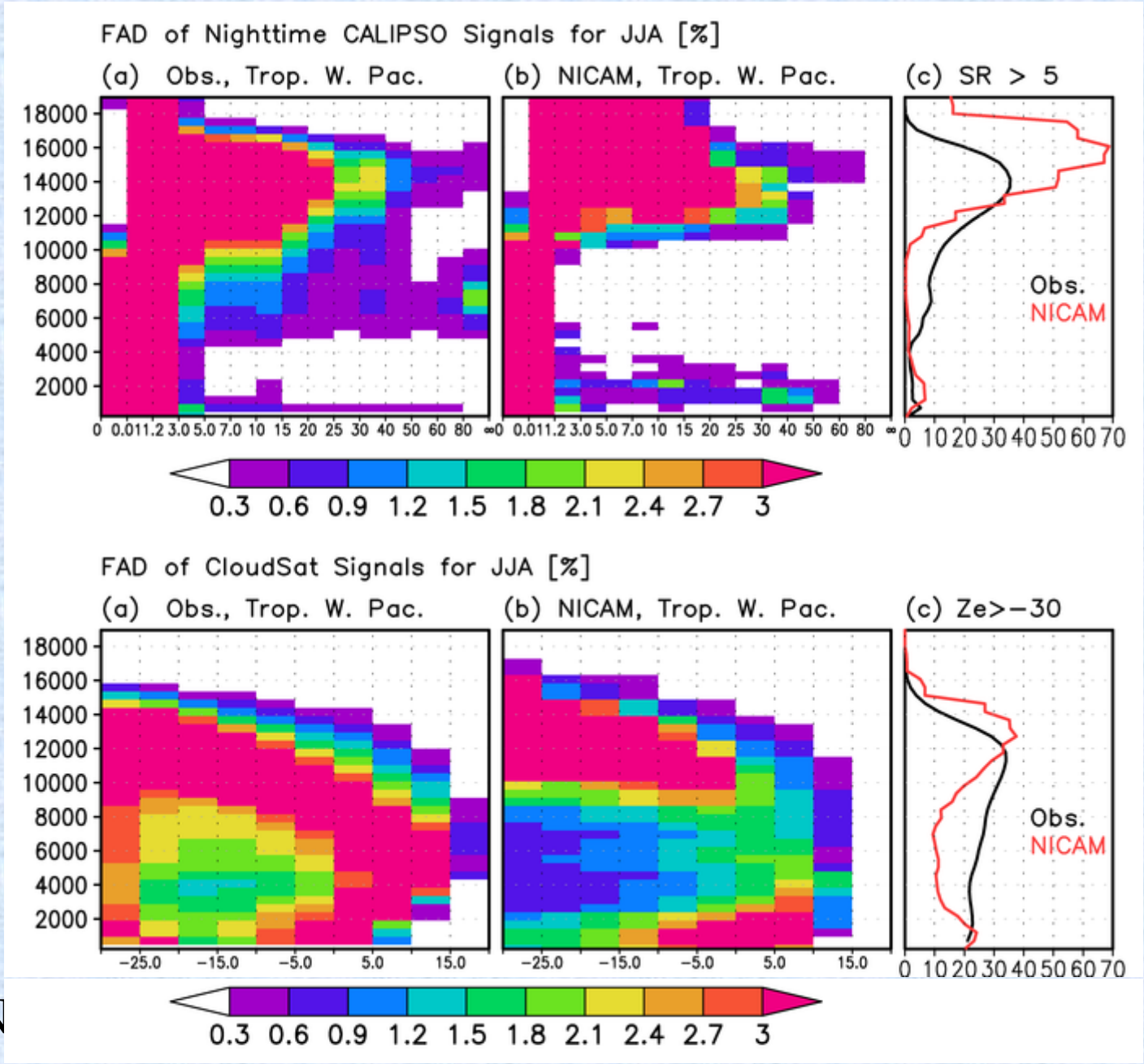


CALIPSO / CloudSat CFAD (Tropical Western Pacific)

CALIPSO

CloudSat

(70-150, 5S-20N

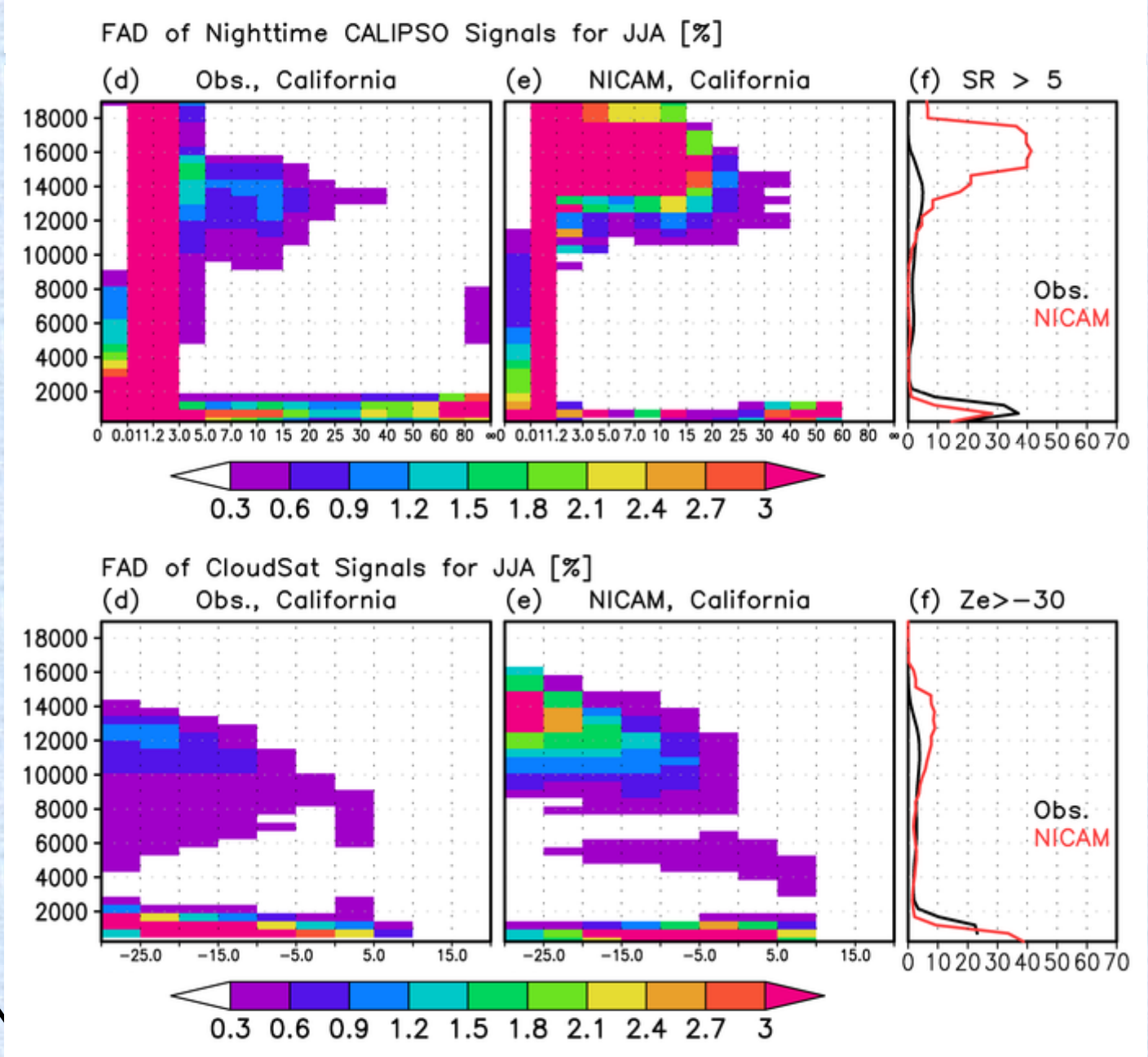


CALIPSO / CloudSat CFAD (Off the California)

CALIPSO

CloudSat

(220-250, 15-35N

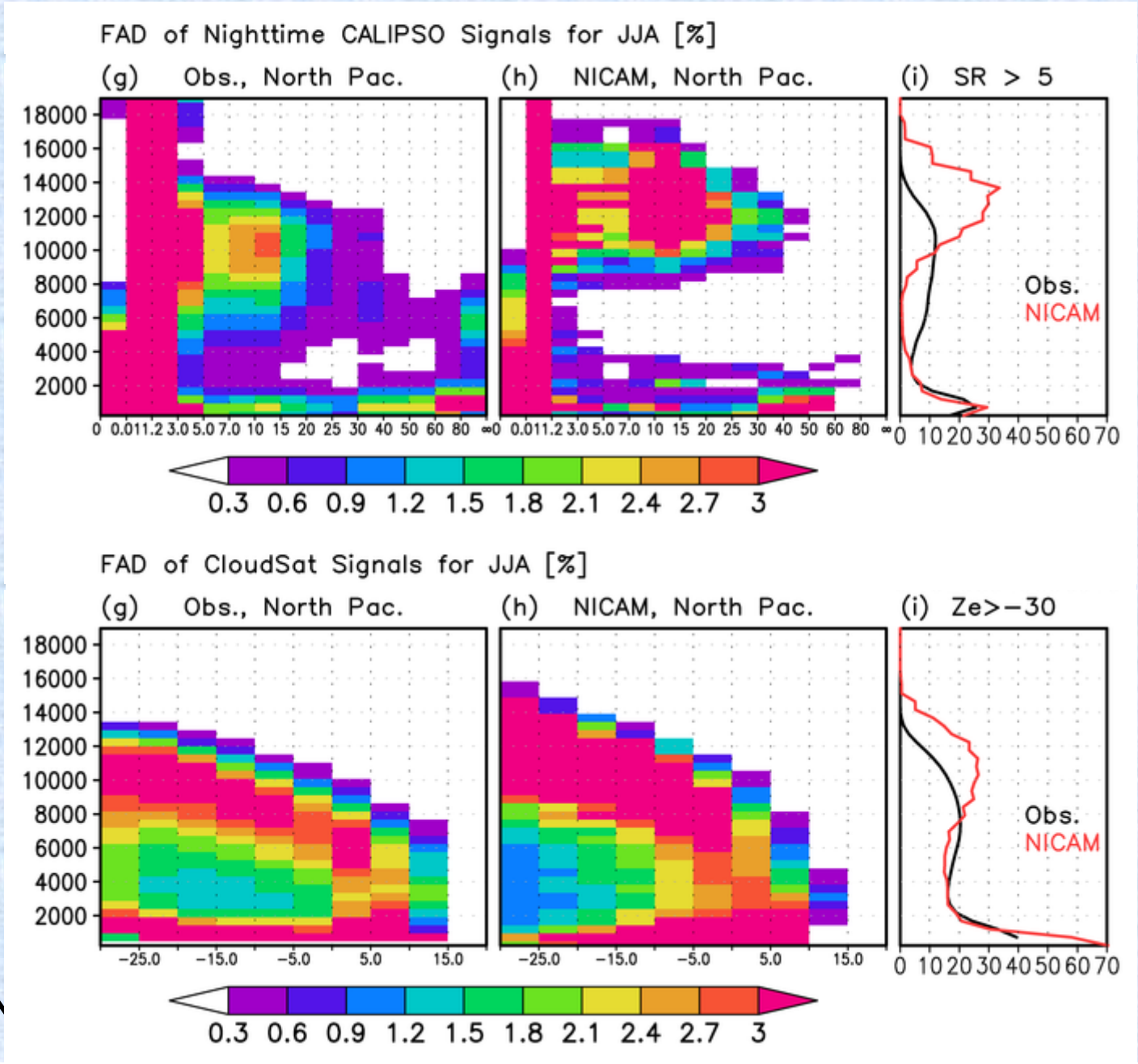


CALIPSO / CloudSat CFAD (North Pacific)

CALIPSO

CloudSat

(160-220, 30-60N



Sensitivity Experiments

- Too much sub-visible thin cirrus!
  - Too much cloud ice!
- Auto-conversion from cloud ice q_i to snow q_s

$$P_{SAUT} = \beta_1 (q_i - q_{icrt}) \quad \text{[g/(kg s)]}$$

(if $P_{SAUT} < 0$, $P_{SAUT} = 0$)

  - q_{icrt}= 0, 0.001, **0.005 (control)**, 0.01, 0.1 [g/kg]
- Fall of cloud ice
  - **no (control)** or yes
  - q_{icrt} = 0

$$V_t = 3.29\,(\rho q_i)^{0.16}$$

Heymsfield and Donner [1990]

10-day integration
last 5-day mean

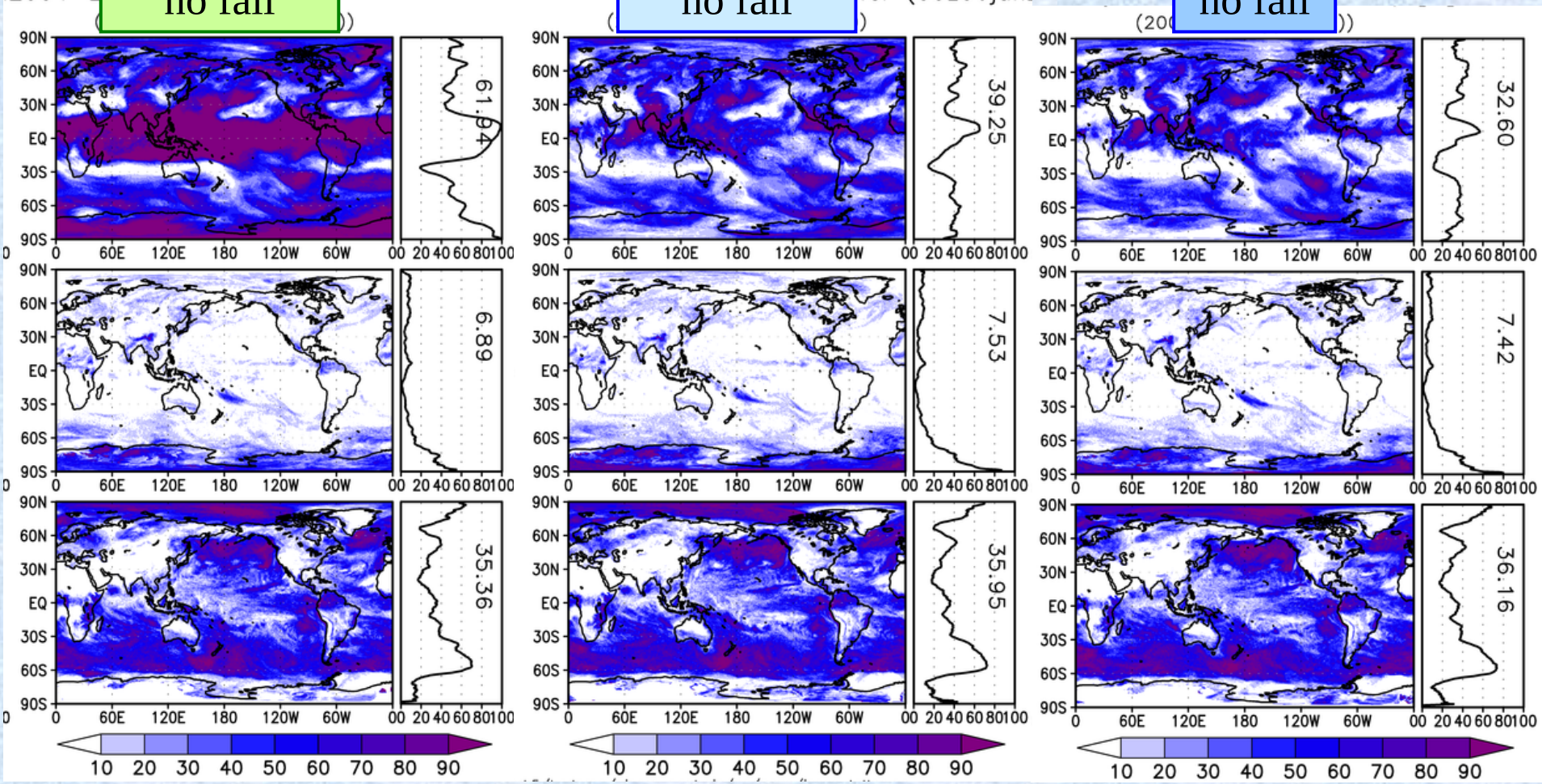
CALIPSO Cloud Fraction for 6-10th days [%] : q_{icrt} → smaller

high cloud
middle cloud
low cloud

q_{icrt} = 0.005
no fall

q_{icrt} = 0.001
no fall

q_{icrt} = 0
no fall



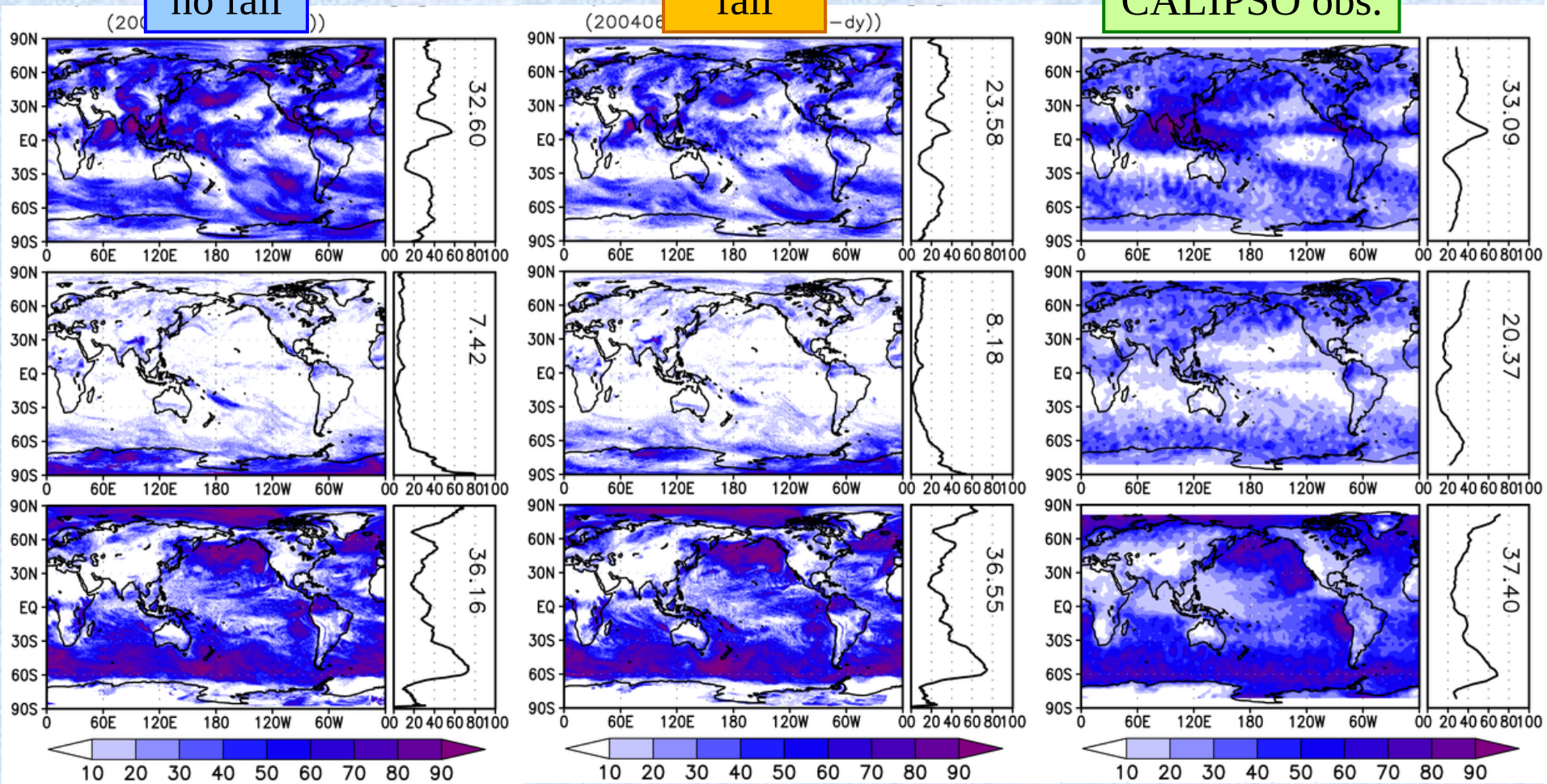
CALIPSO Cloud Fraction for 6-10th days : cloud ice fall off/on

high cloud
middle cloud
low cloud

q_{icrt} = 0
no fall

q_{icrt} = 0
fall

CALIPSO obs.

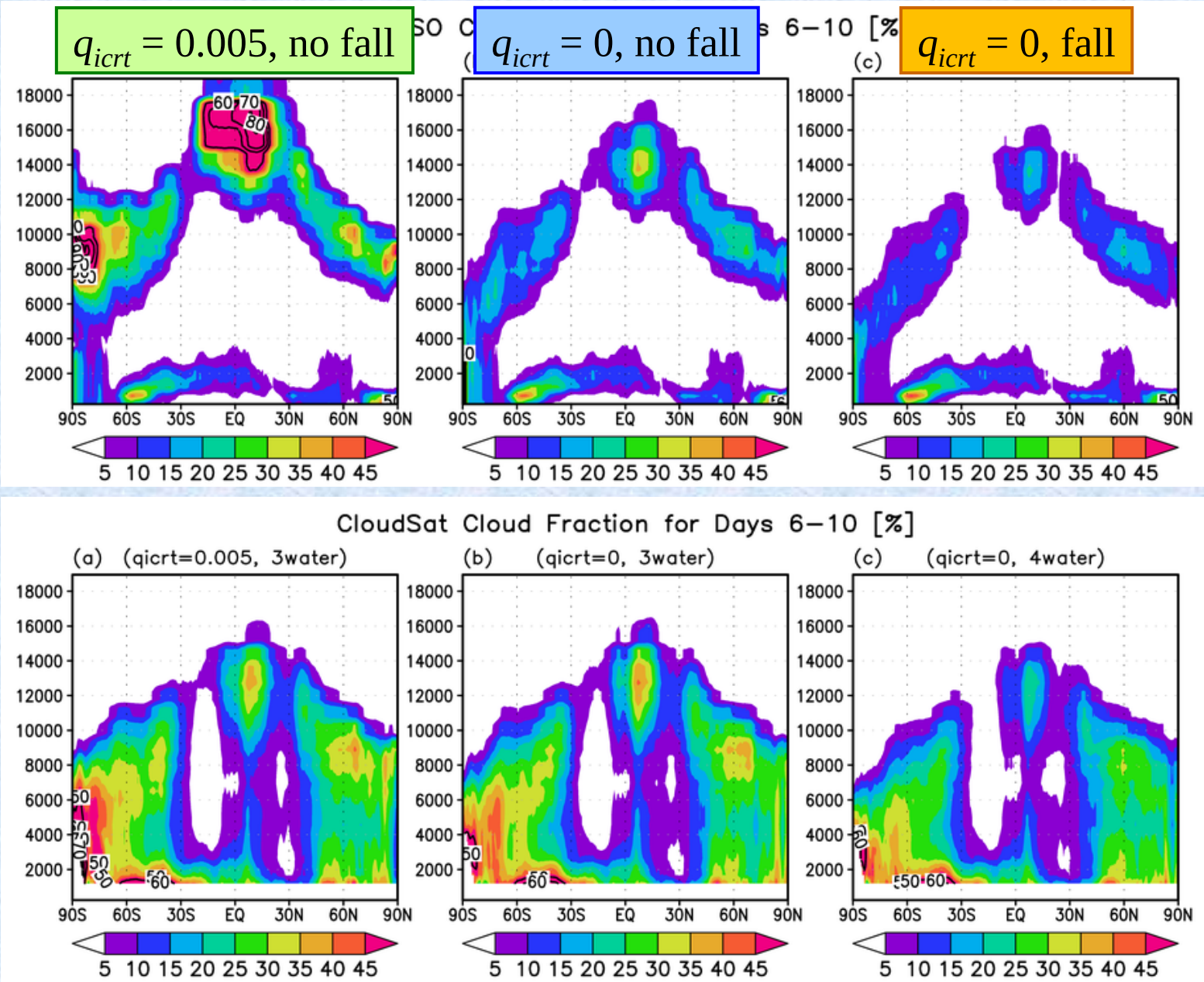


* obs: June-Mean

Zonal Mean CALIPSO / CloudSat Cloud Fractions

CALIPSO

CloudSat



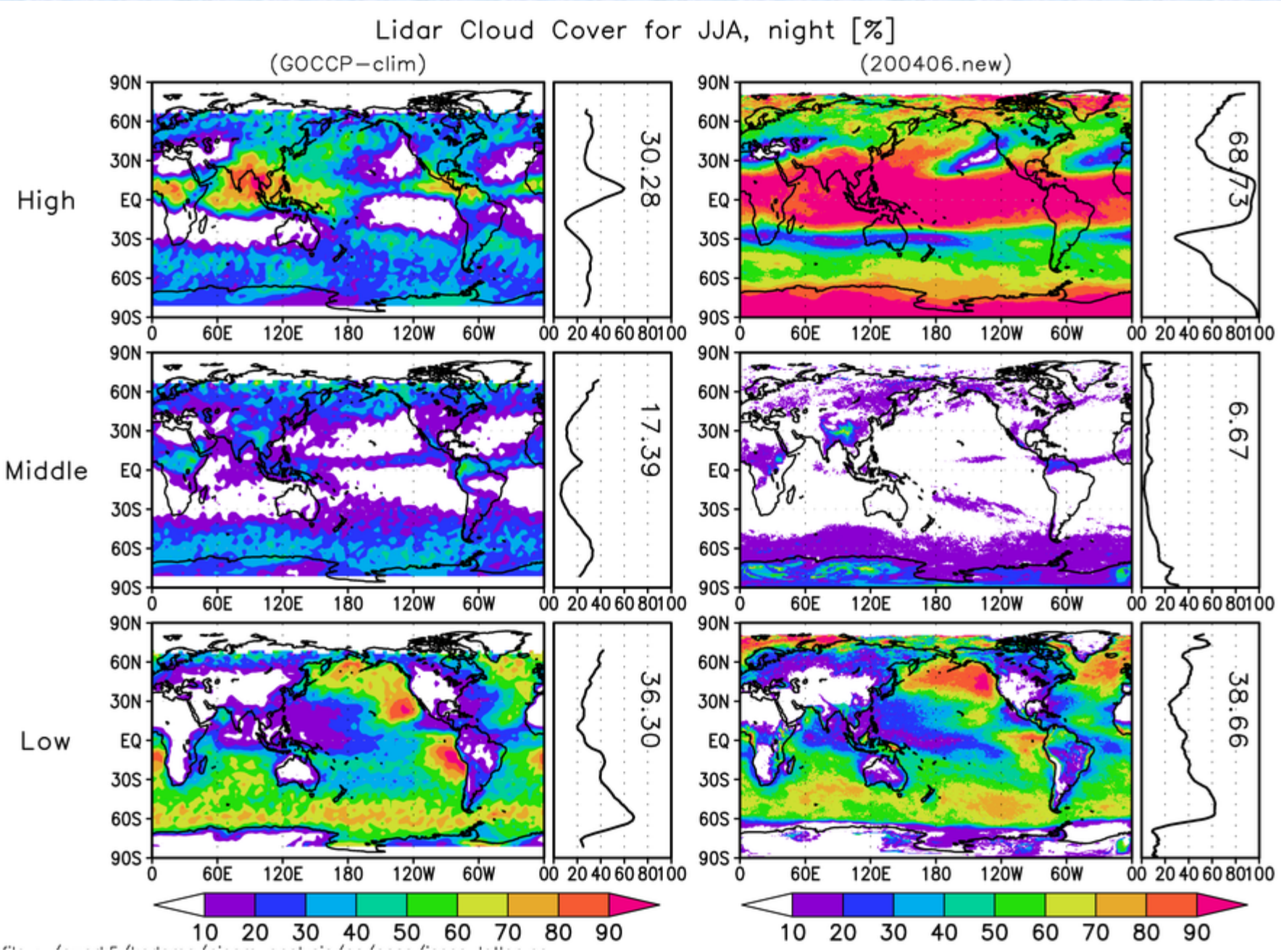
Summary

- Satellite obs. vs. NICAM+COSP
  - High cloud: overestimated（esp. thin cloud）, higher cloud top
  - Middle cloud: underestimated
  - Low cloud: good
  - Precipitation: overestimated
- Sensitivity experiments
  - greater conversion from cloud ice to snow
  - fall of cloud ice
  - ・・・ both reduce high cloud & cloud top height
- Future
  - higher horizontal resolution, specific phenomena, ...

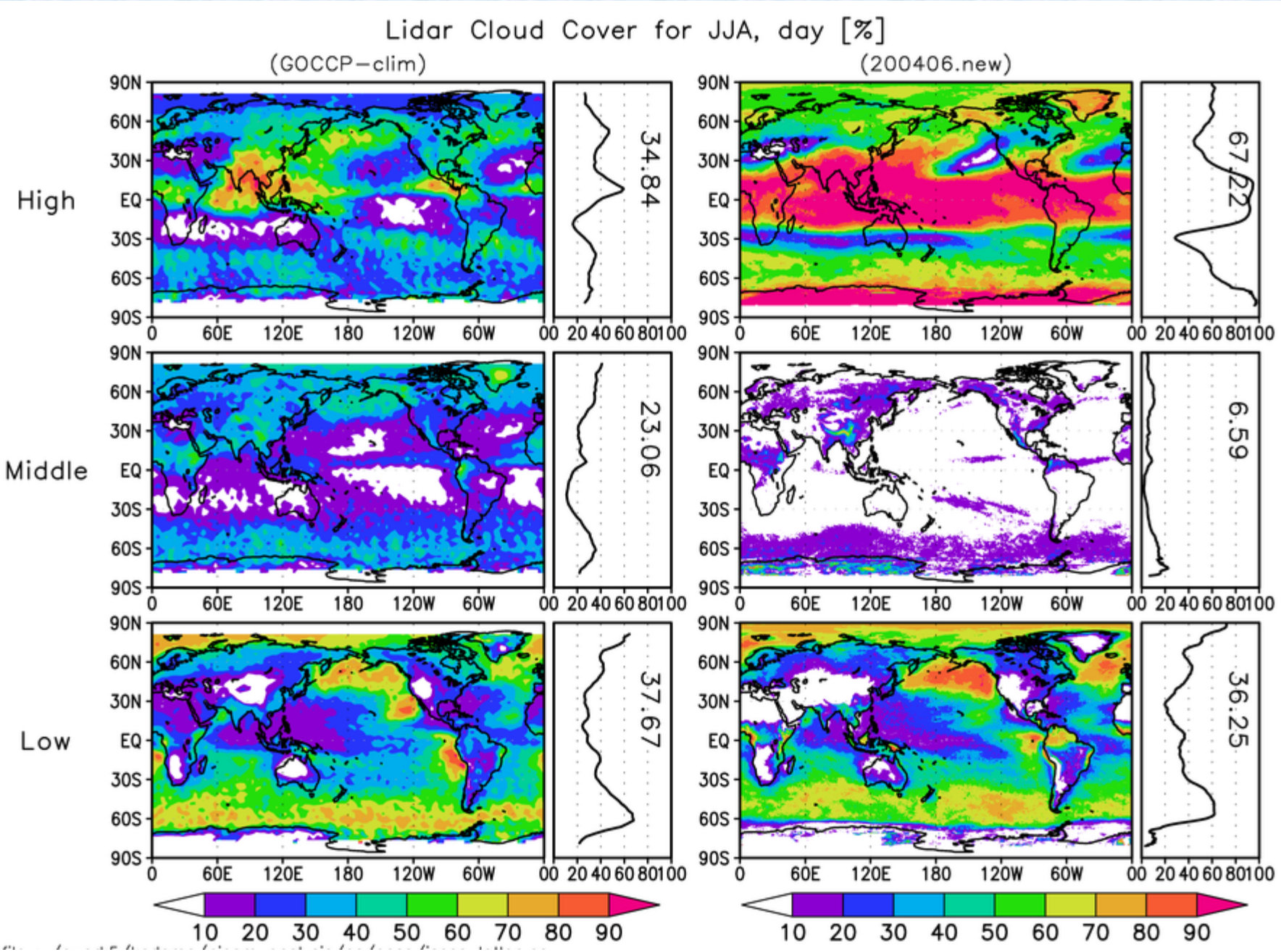
Appendix

(bias, COSP)

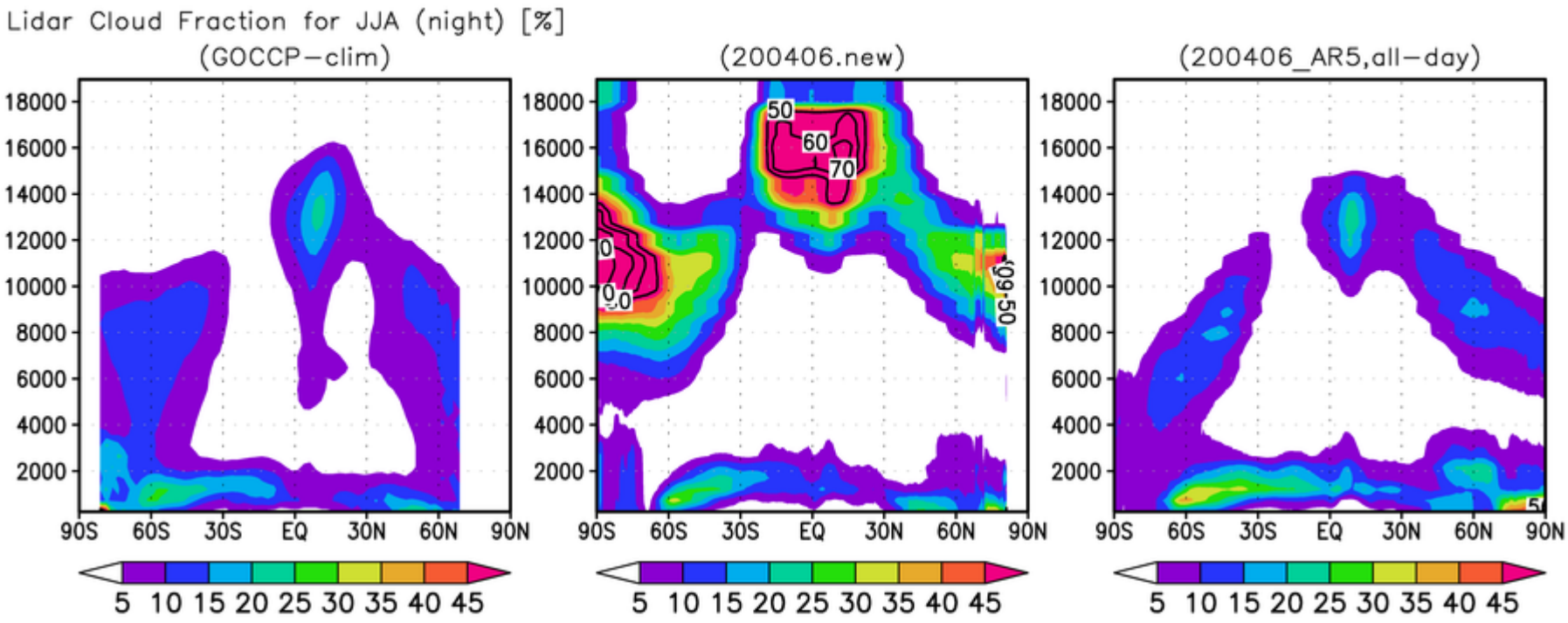
ls_cldlayer_night_JJA.png



ls_cldlayer_day_JJA.png



ls_lidarcld_night_JJA.png



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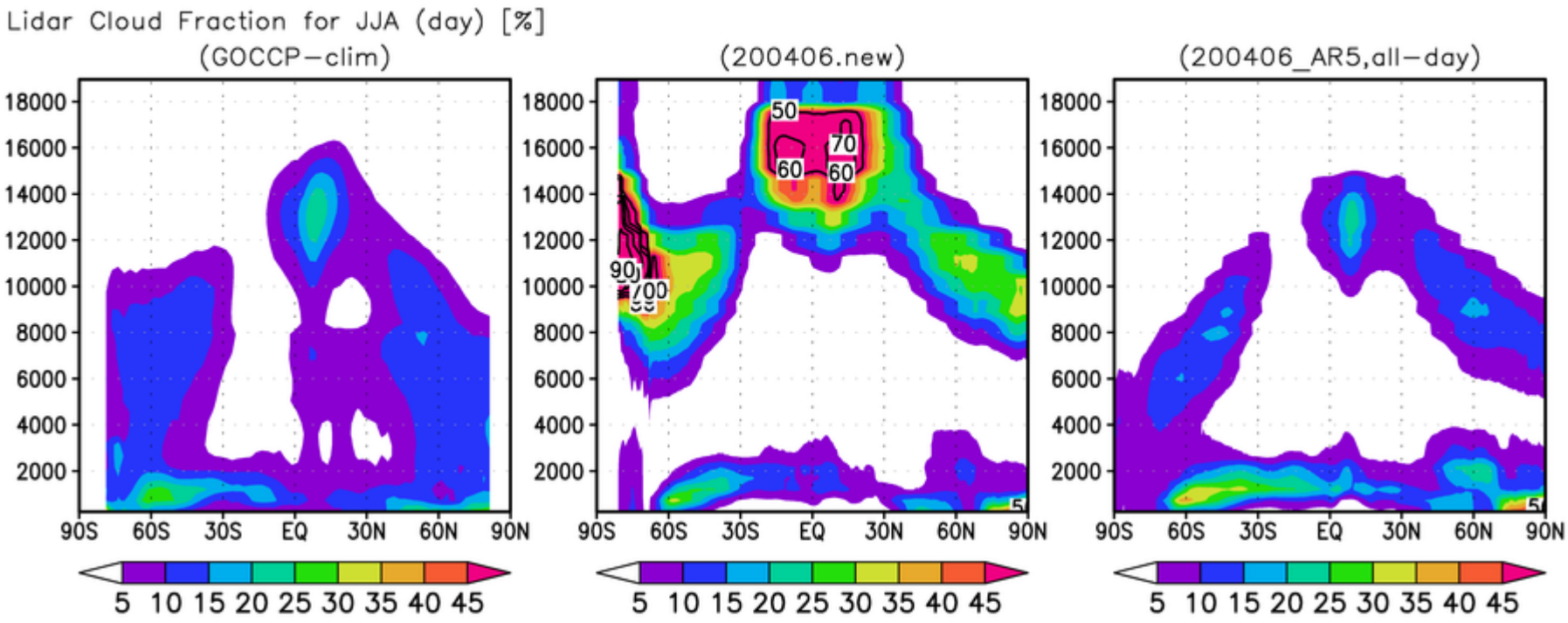
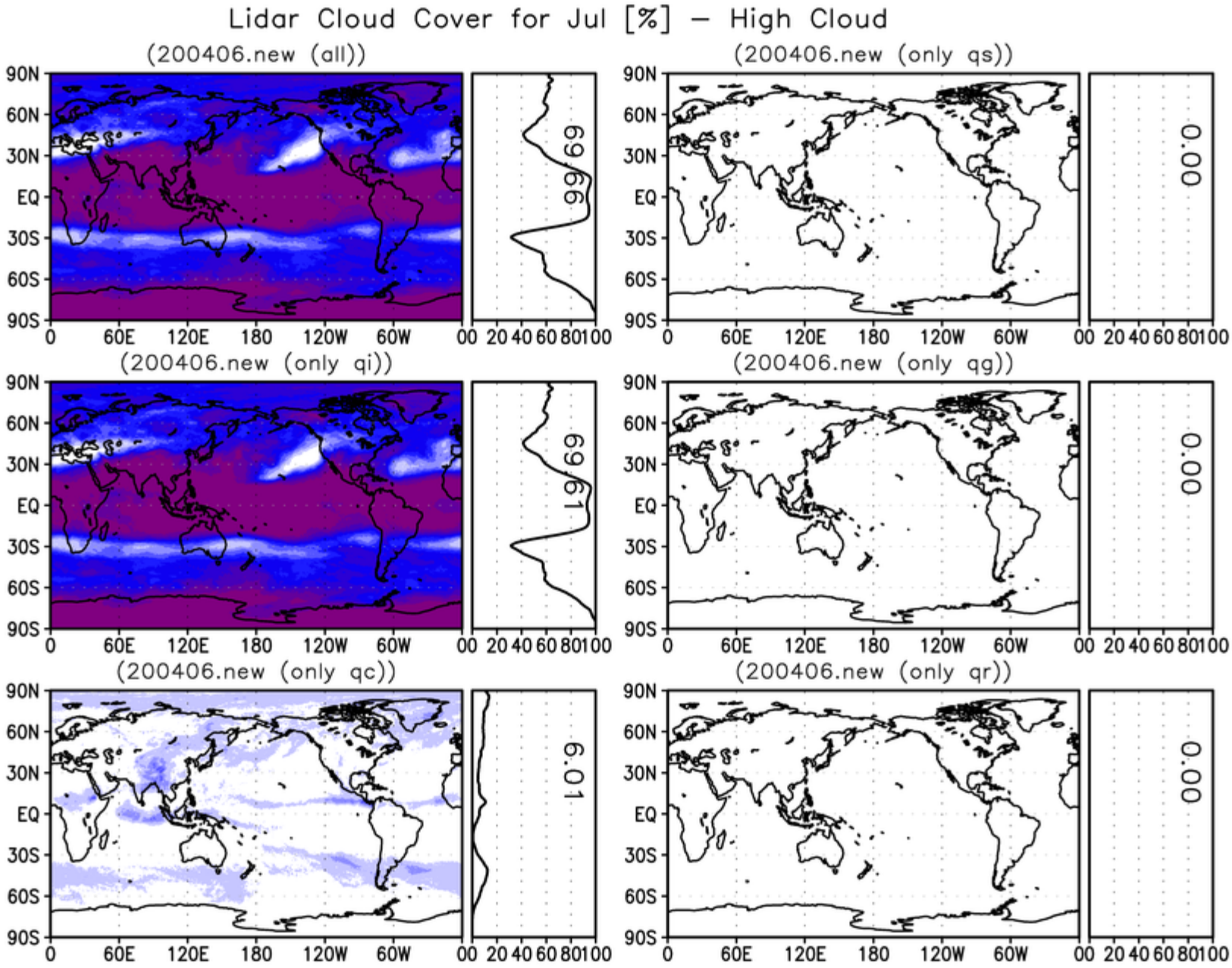
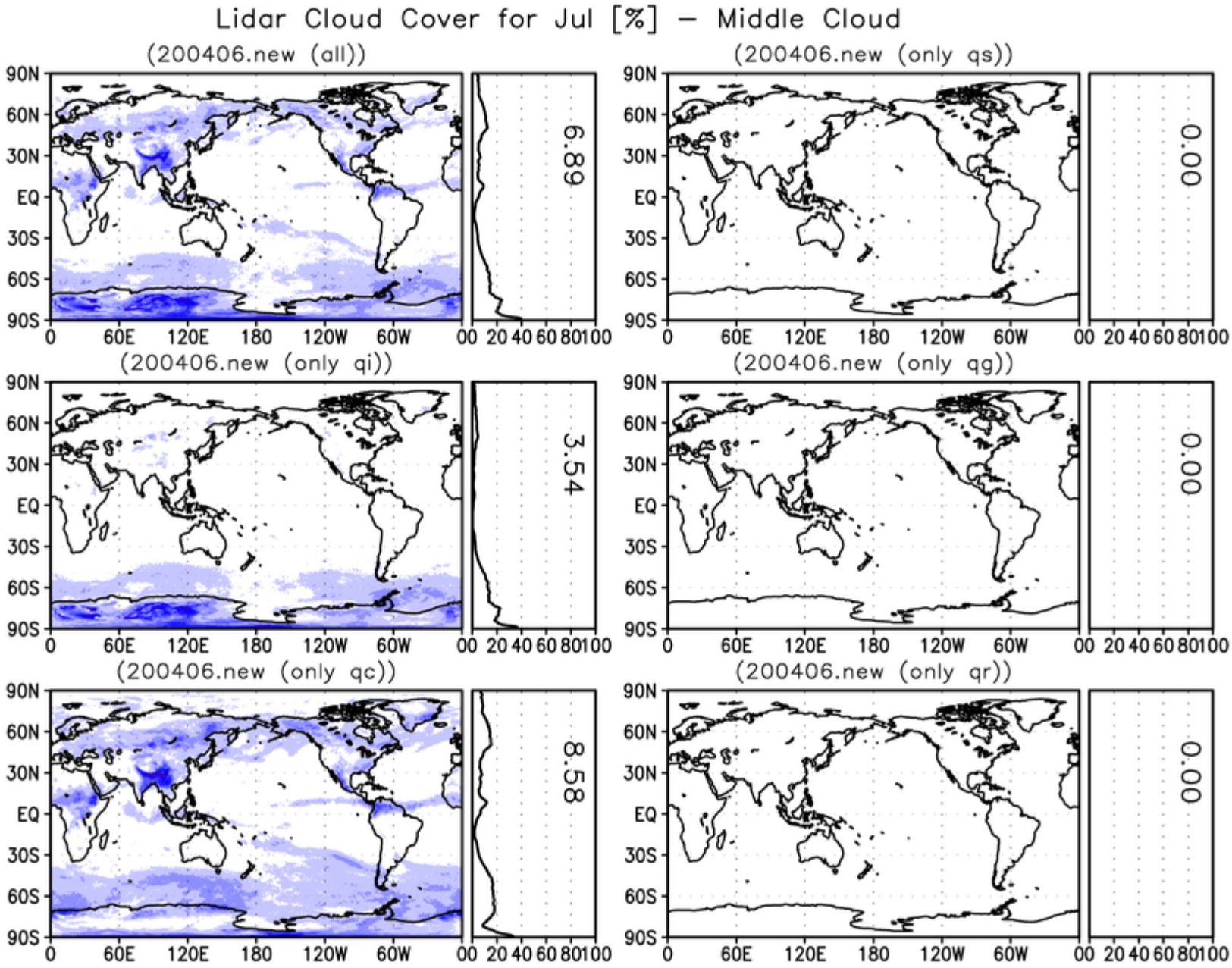


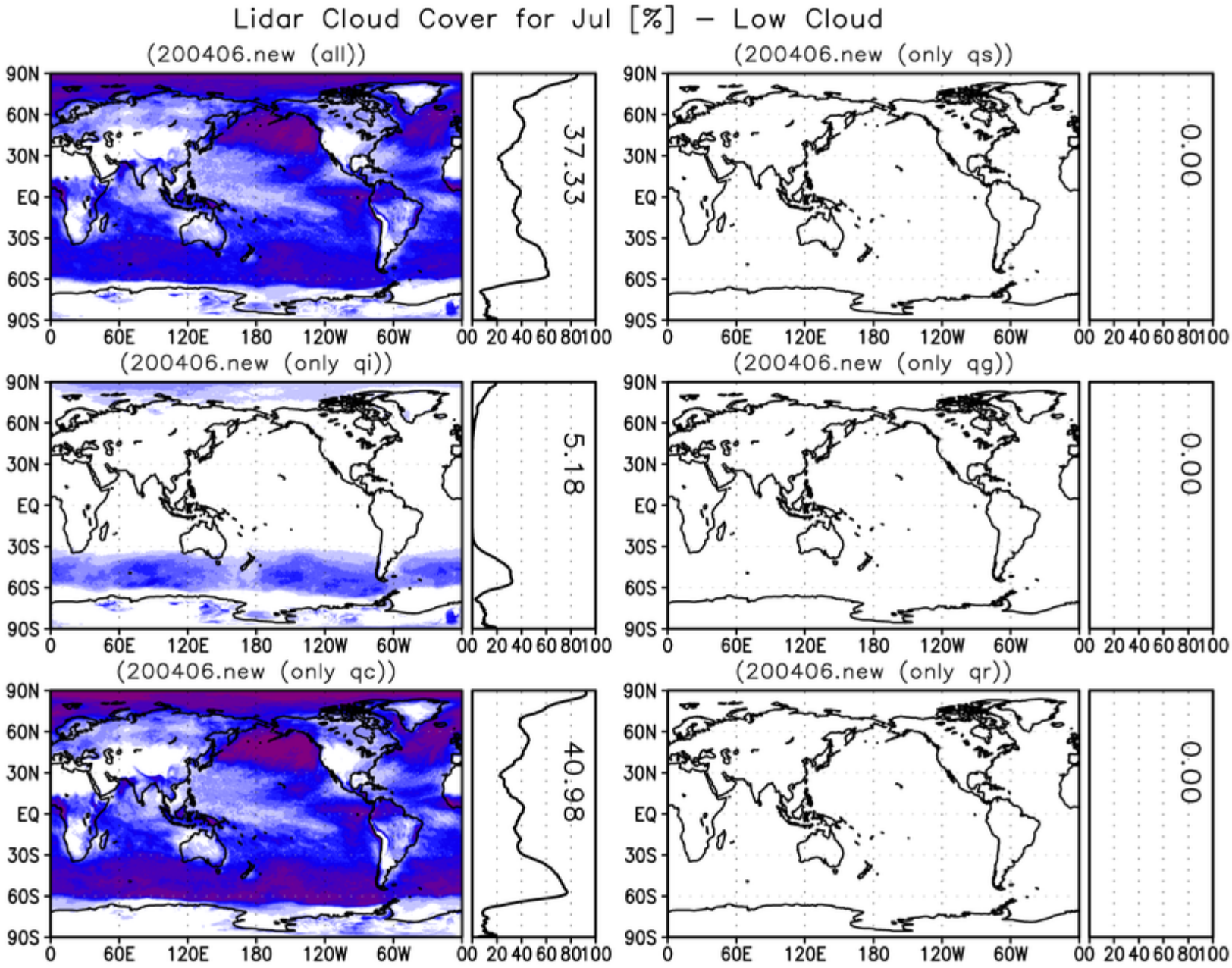
Lidar Cloud Fraction (High Cloud)



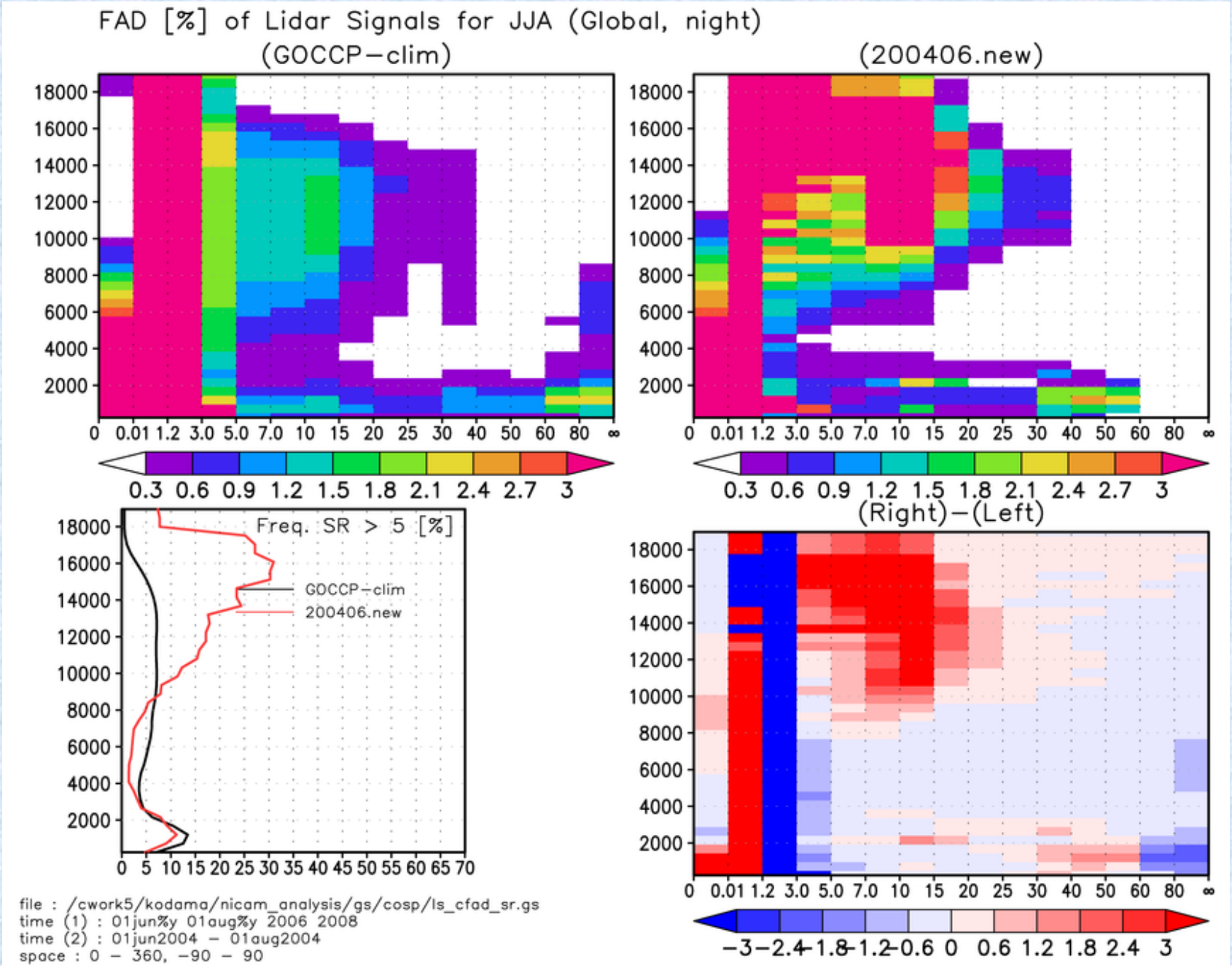
Lidar Cloud Fraction (Middle Cloud)



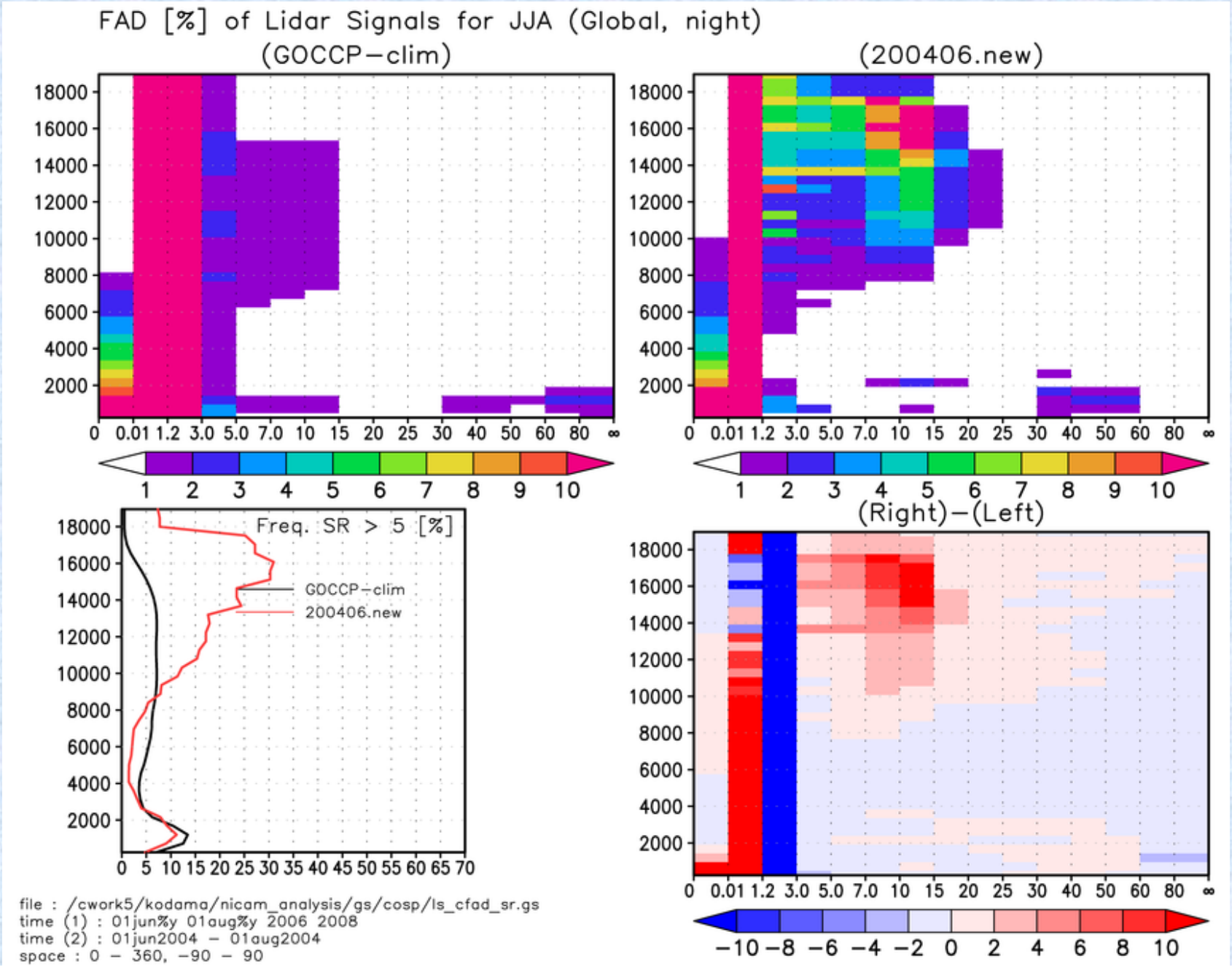
Lidar Cloud Fraction (Low Cloud)

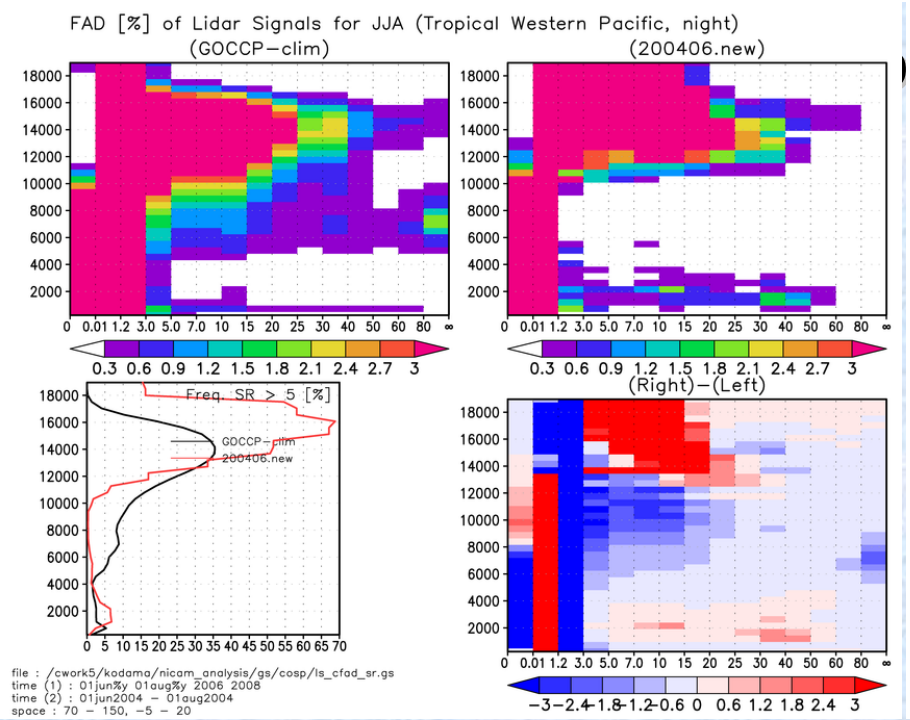


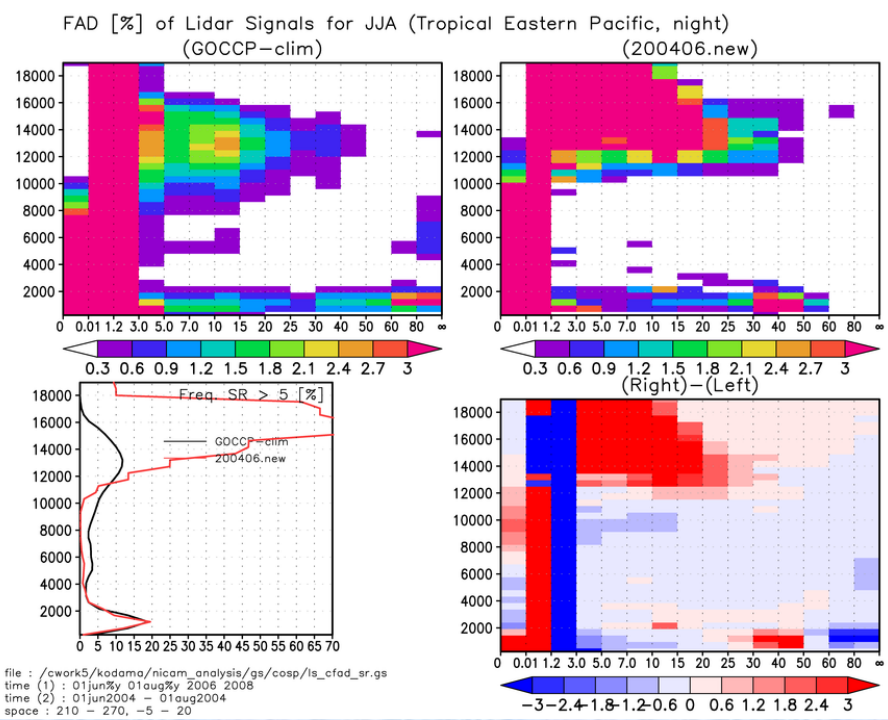
ls_cfad_sr_global_JJA_night_type2.png

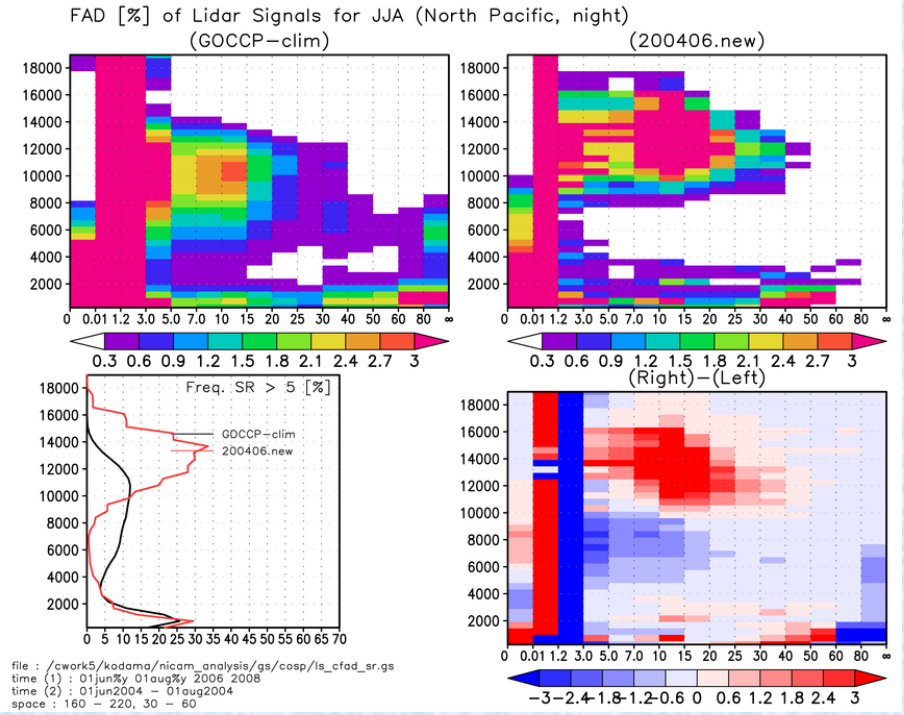


ls_cfad_sr_global_JJA_night_type1.png




FAD [%] of Lidar Signals for JJA (Tropical Western Pacific, night)
(GOCCP−clim)
(200406.new)
Freq. SR > 5 [%]
GOCCP−clim
200406.new
(Right)−(Left)
file : /cwork5/kodama/nicam_analysis/gs/cosp/ls_cfad_sr.gs
time (1) : 01jun%y 01aug%y 2006 2008
time (2) : 01jun2004 − 01aug2004
space : 70 − 150, −5 − 20


FAD [%] of Lidar Signals for JJA (Tropical Eastern Pacific, night)
(GOCCP−clim)
(200406.new)
Freq. SR > 5 [%]
GOCCP−clim
200406.new
(Right)−(Left)
file : /cwork5/kodama/nicam_analysis/gs/cosp/ls_cfad_sr.gs
time (1) : 01jun%y 01aug%y 2006 2008
time (2) : 01jun2004 − 01aug2004
space : 210 − 270, −5 − 20


FAD [%] of Lidar Signals for JJA (North Pacific, night)
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(200406.new)
Freq. SR > 5 [%]
GOCCP−clim
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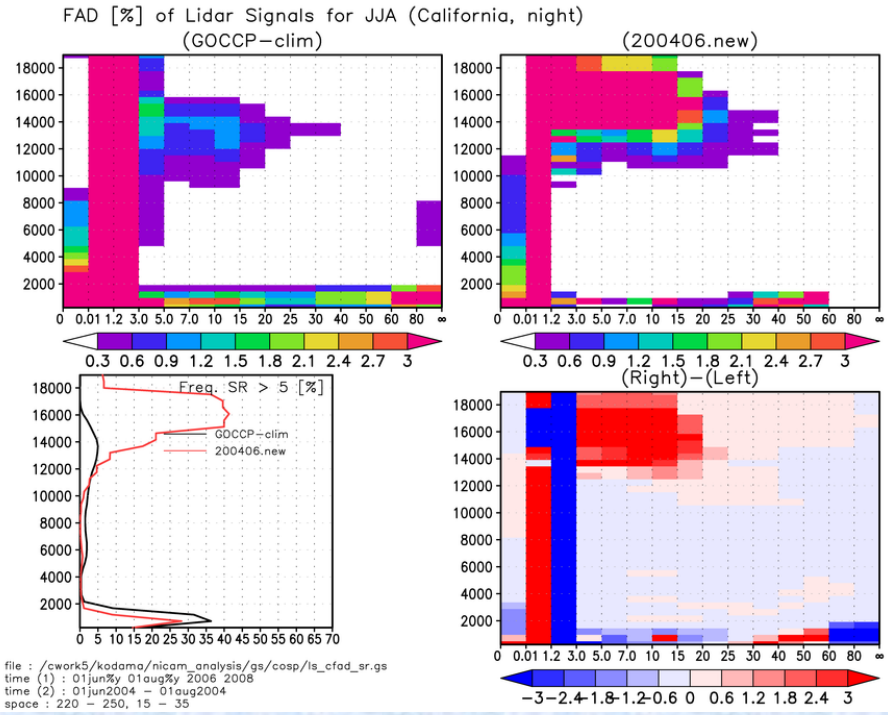
(Right)−(Left)
file : /cwork5/kodama/nicam_analysis/gs/cosp/ls_cfad_sr.gs
time (1) : 01jun%y 01aug%y 2006 2008
time (2) : 01jun2004 − 01aug2004
space : 160 − 220, 30 − 60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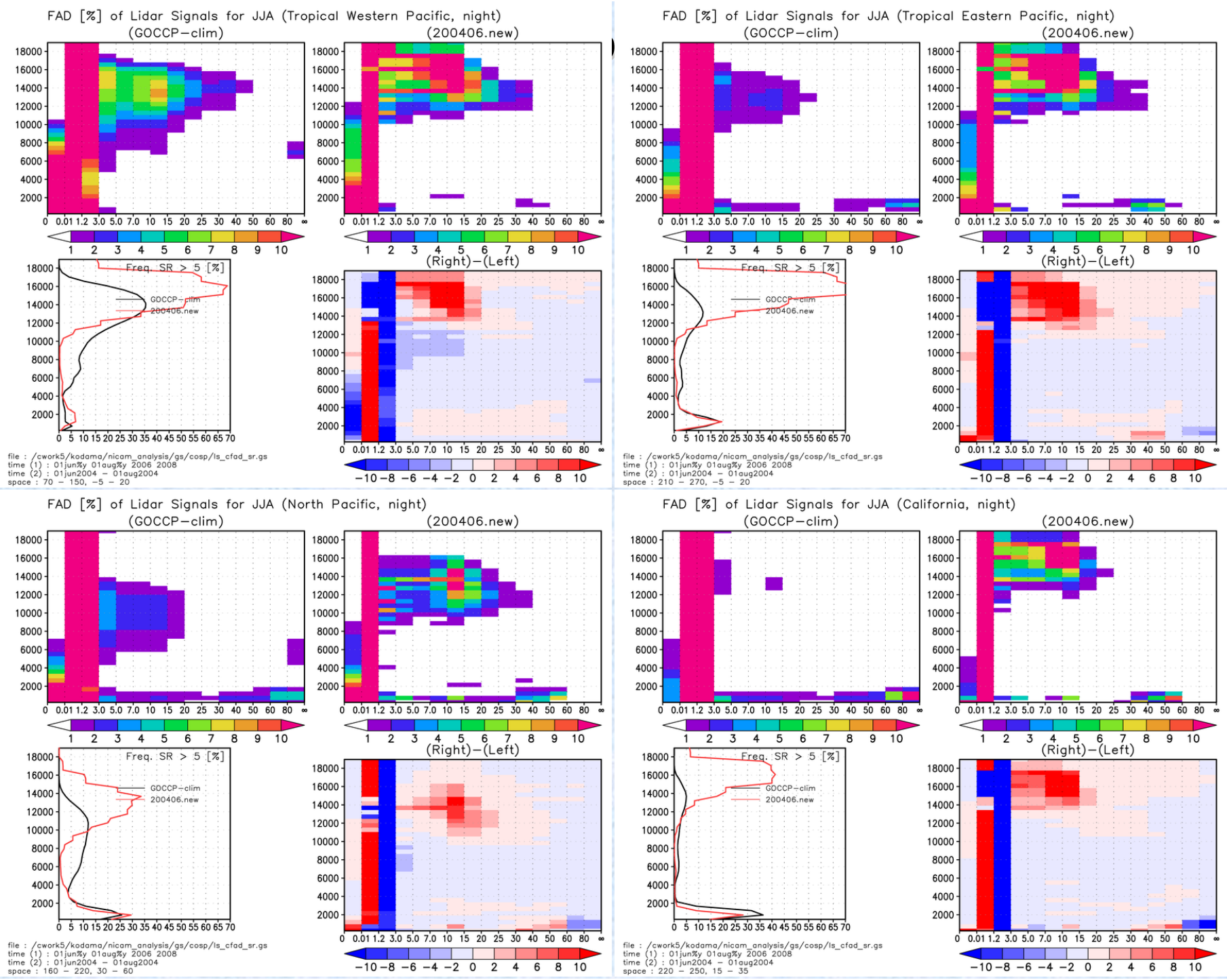
time (1) : 01jun%y 01aug%y 2006 2008
time (2) : 01jun2004 − 01aug2004
space : 220 − 250, 15 − 35


FAD [%] of Lidar Signals for JJA (Tropical Western Pacific, night)
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(200406.new)
Freq. SR > 5 [%]
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(Right)−(Left)
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time (1) : 01jun%y 01aug%y 2006 2008
time (2) : 01jun2004 − 01aug2004
space : 70 − 150, −5 − 20
FAD [%] of Lidar Signals for JJA (Tropical Eastern Pacific, night)
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time (1) : 01jun%y 01aug%y 2006 2008
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space : 210 − 270, −5 − 20
FAD [%] of Lidar Signals for JJA (North Pacific, night)
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Freq. SR > 5 [%]
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space : 160 − 220, 30 − 60
FAD [%] of Lidar Signals for JJA (California, night)
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Freq. SR > 5 [%]
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time (1) : 01jun%y 01aug%y 2006 2008
time (2) : 01jun2004 − 01aug2004
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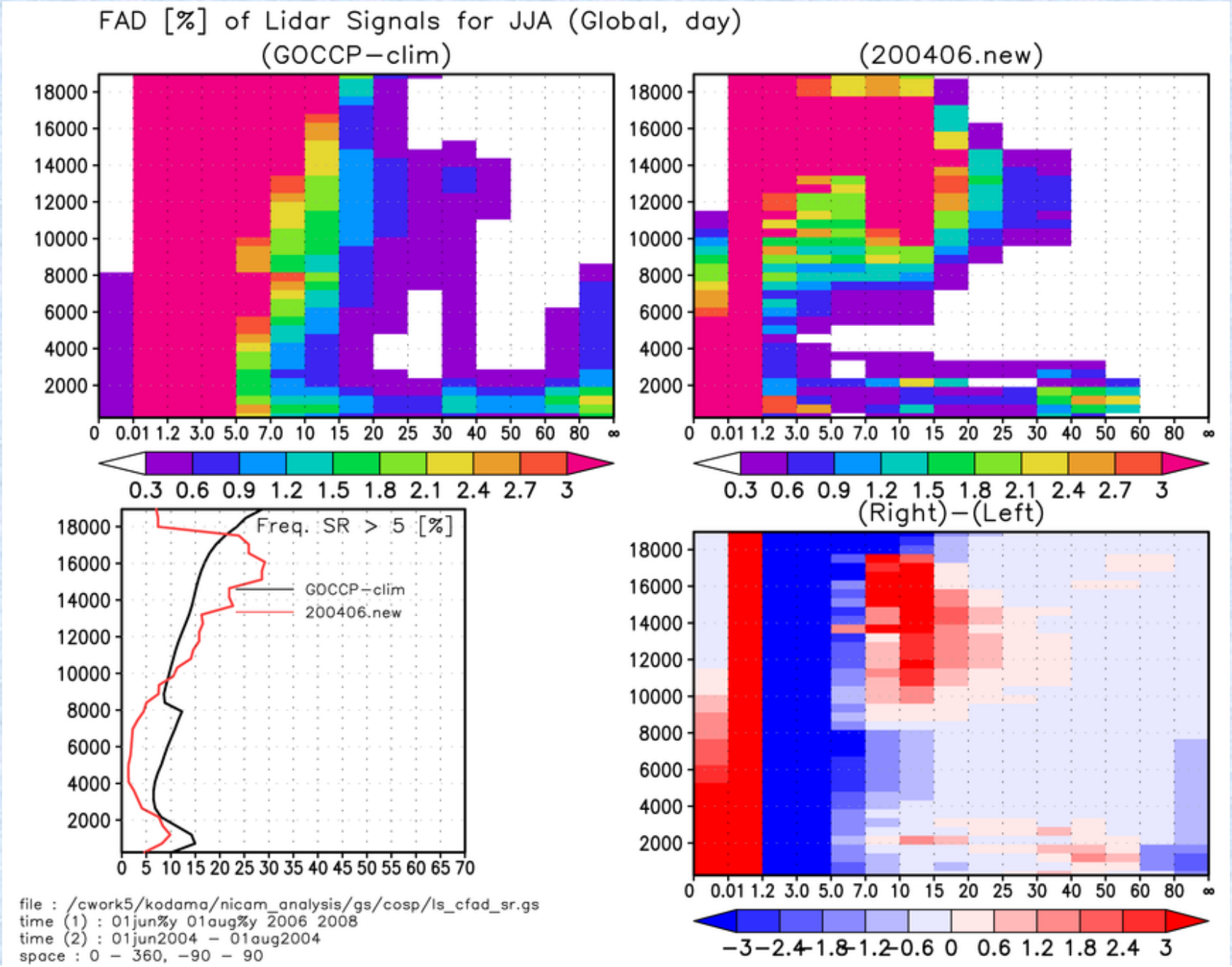
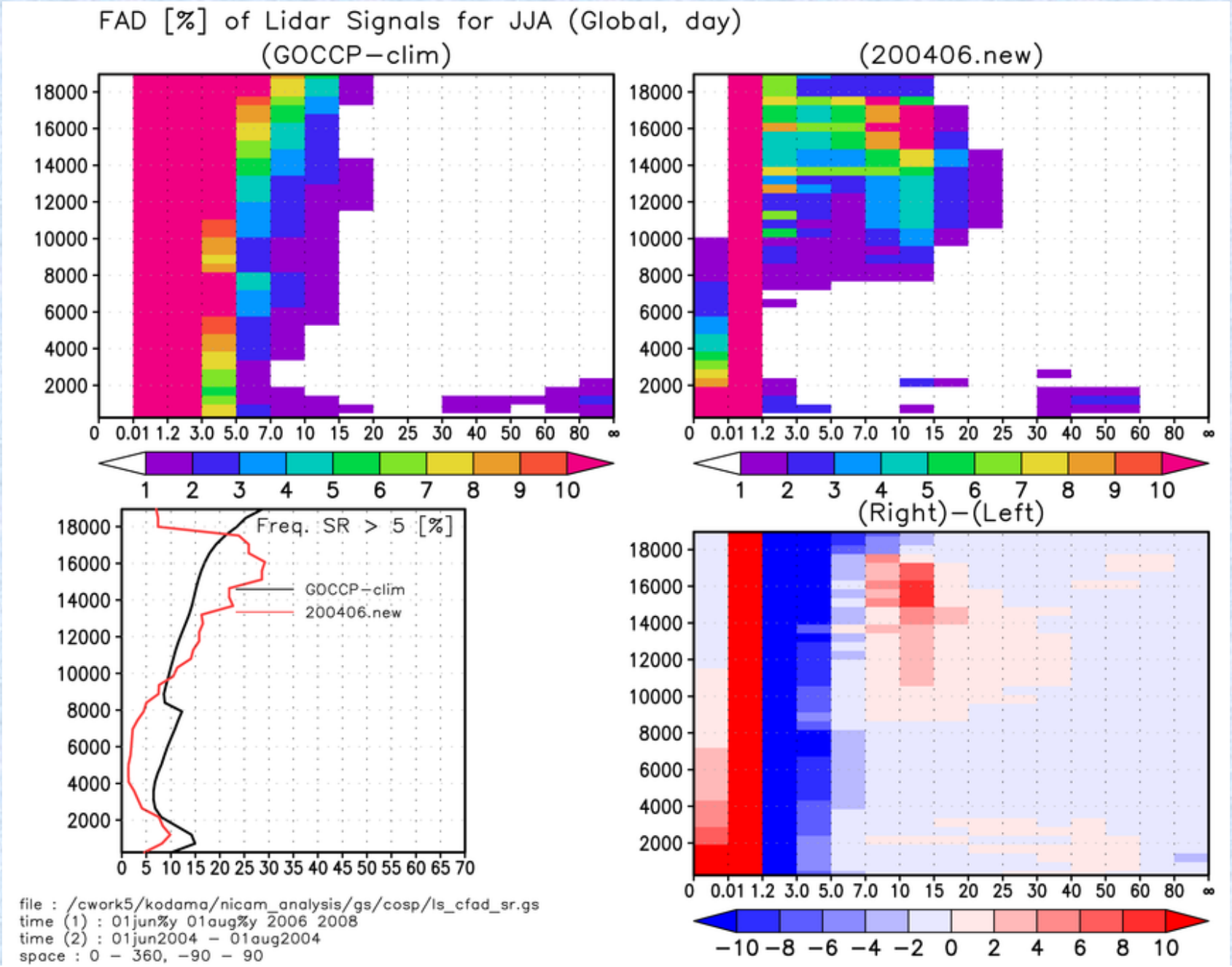
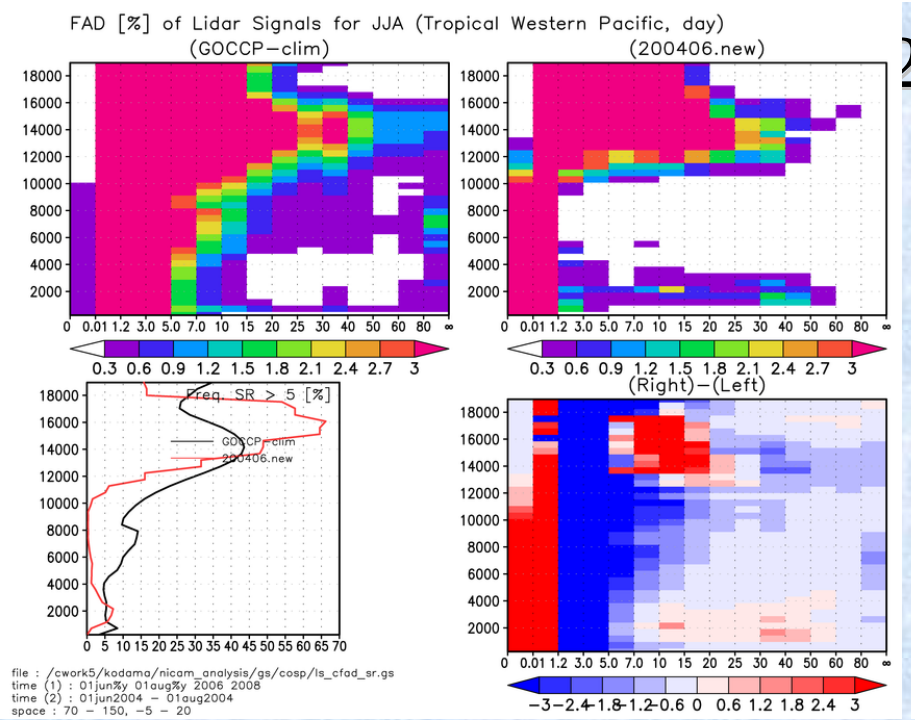
ls_cfad_sr_global_JJA_day_type2.png



ls_cfad_sr_global_JJA_day_type1.png




FAD [%] of Lidar Signals for JJA (Tropical Western Pacific, day)
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(200406.new)
(Right)−(Left)
Freq. SR > 5 [%]
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time (1) : 01jun%y 01aug%y 2006 2008
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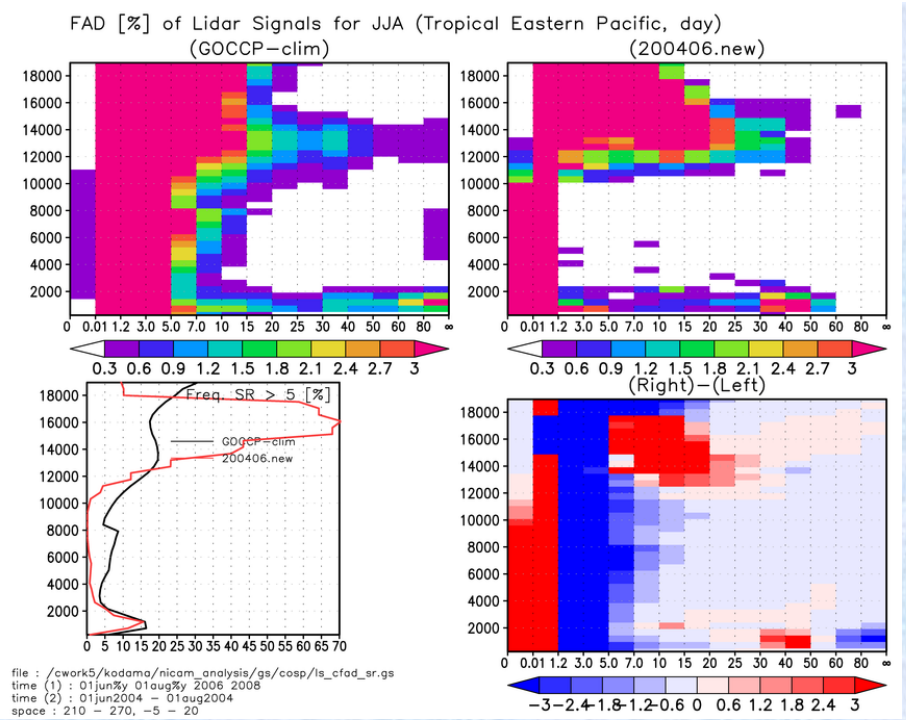
space : 70 − 150, −5 − 20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(200406.new)
(Right)−(Left)
Freq. SR > 5 [%]
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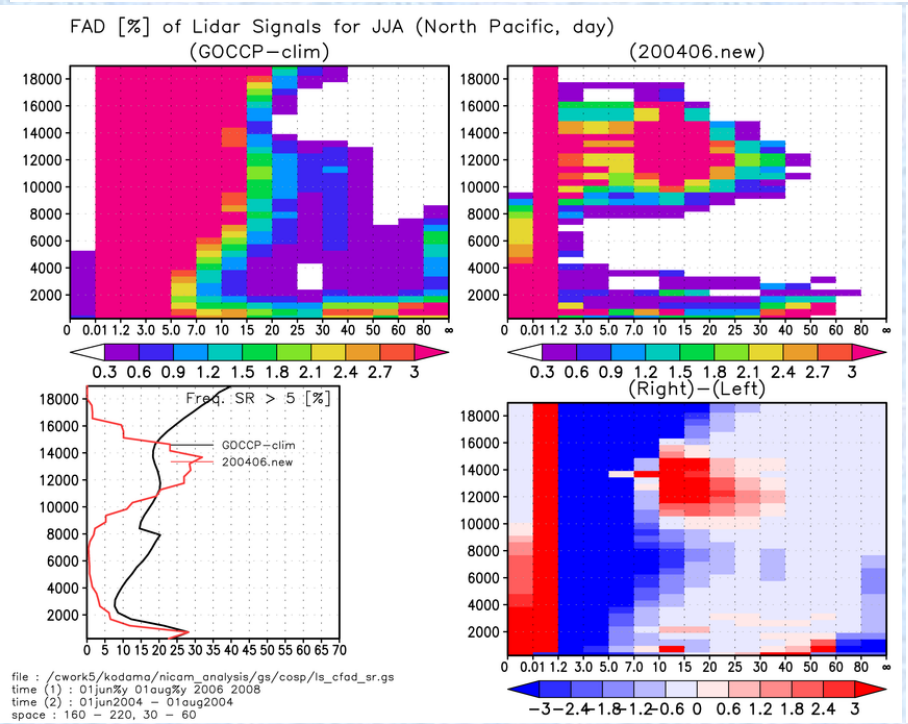
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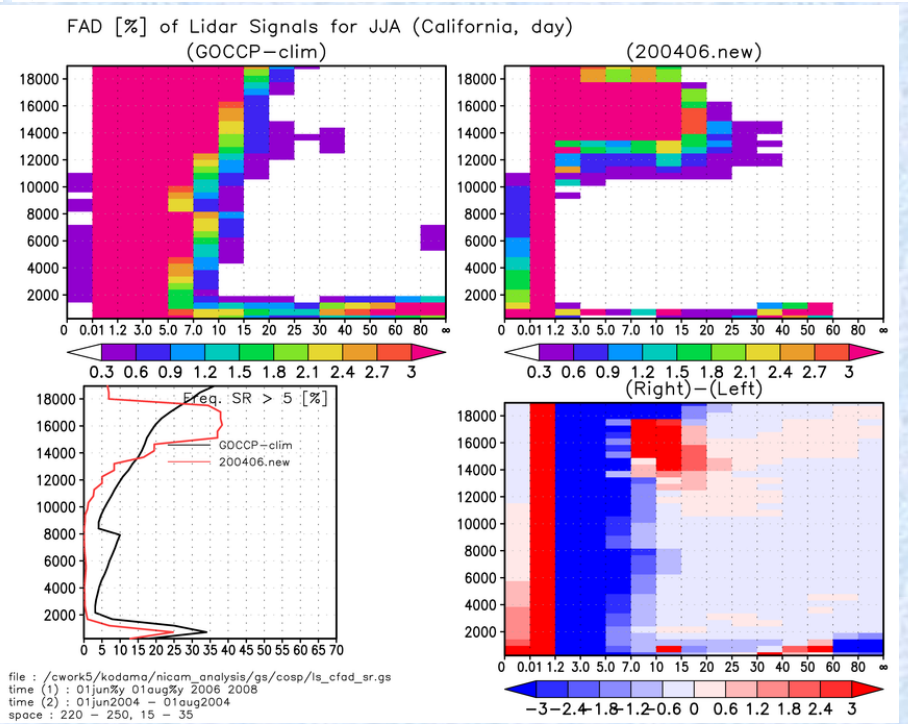
FAD [%] of Lidar Signals for JJA (California, day)
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(200406.new)
(Right)−(Left)
Freq. SR > 5 [%]
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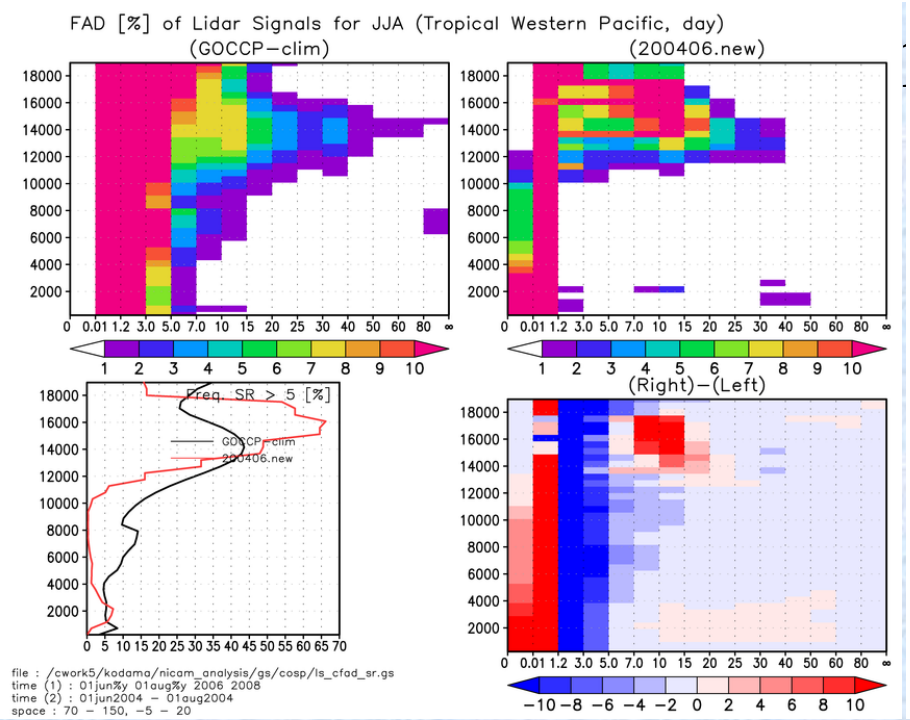
space : 220 − 250, 15 − 35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(200406.new)
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GOCCP−clim
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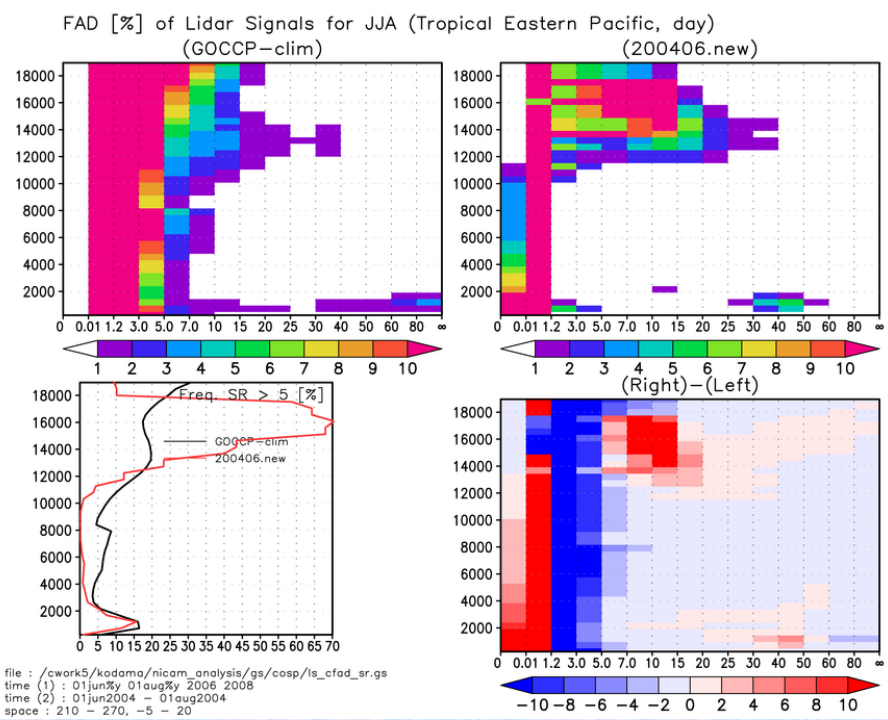
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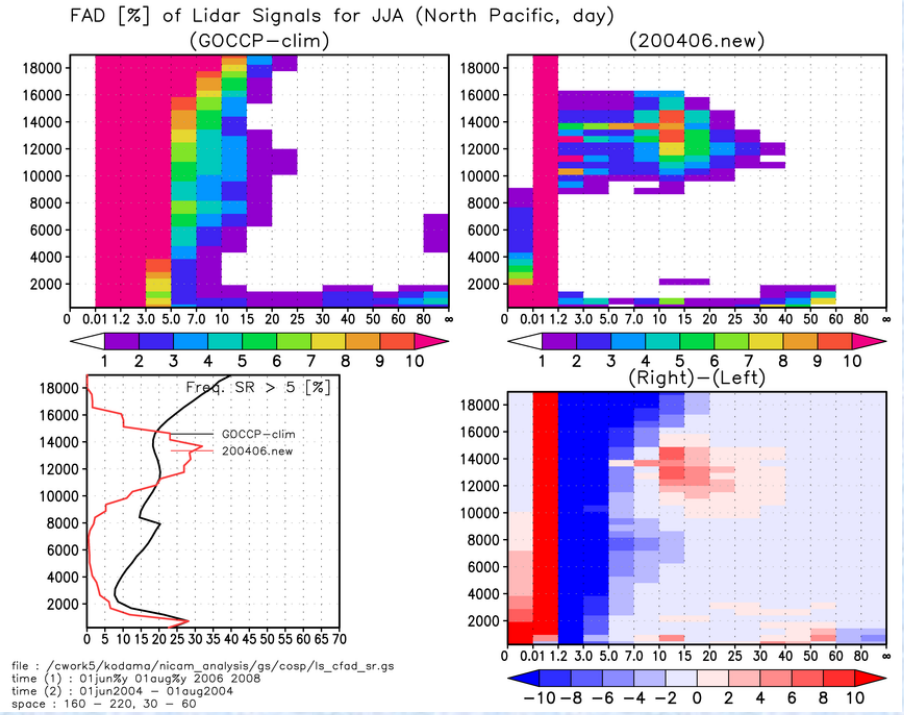
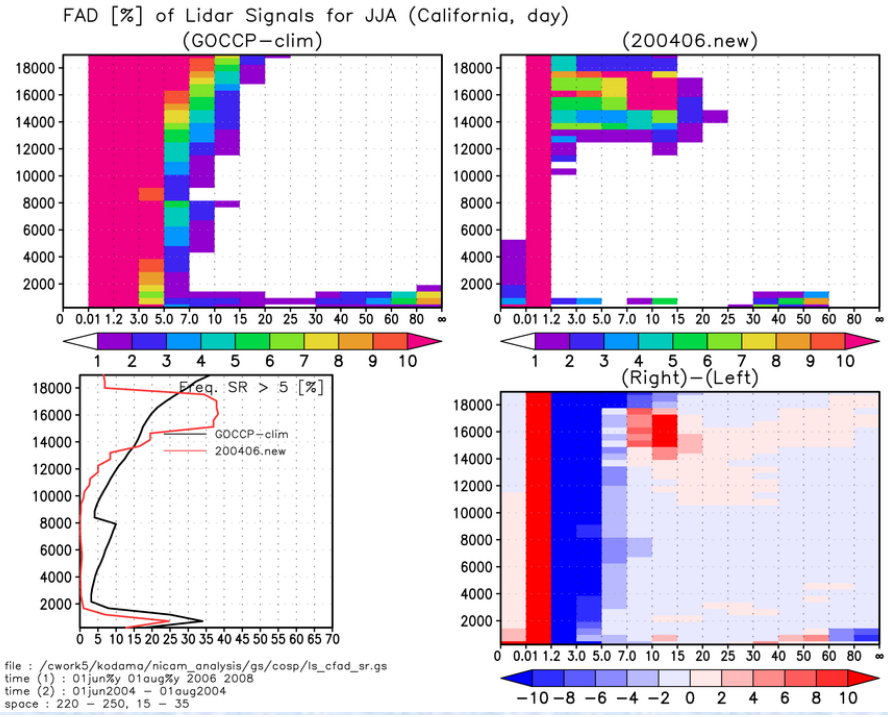
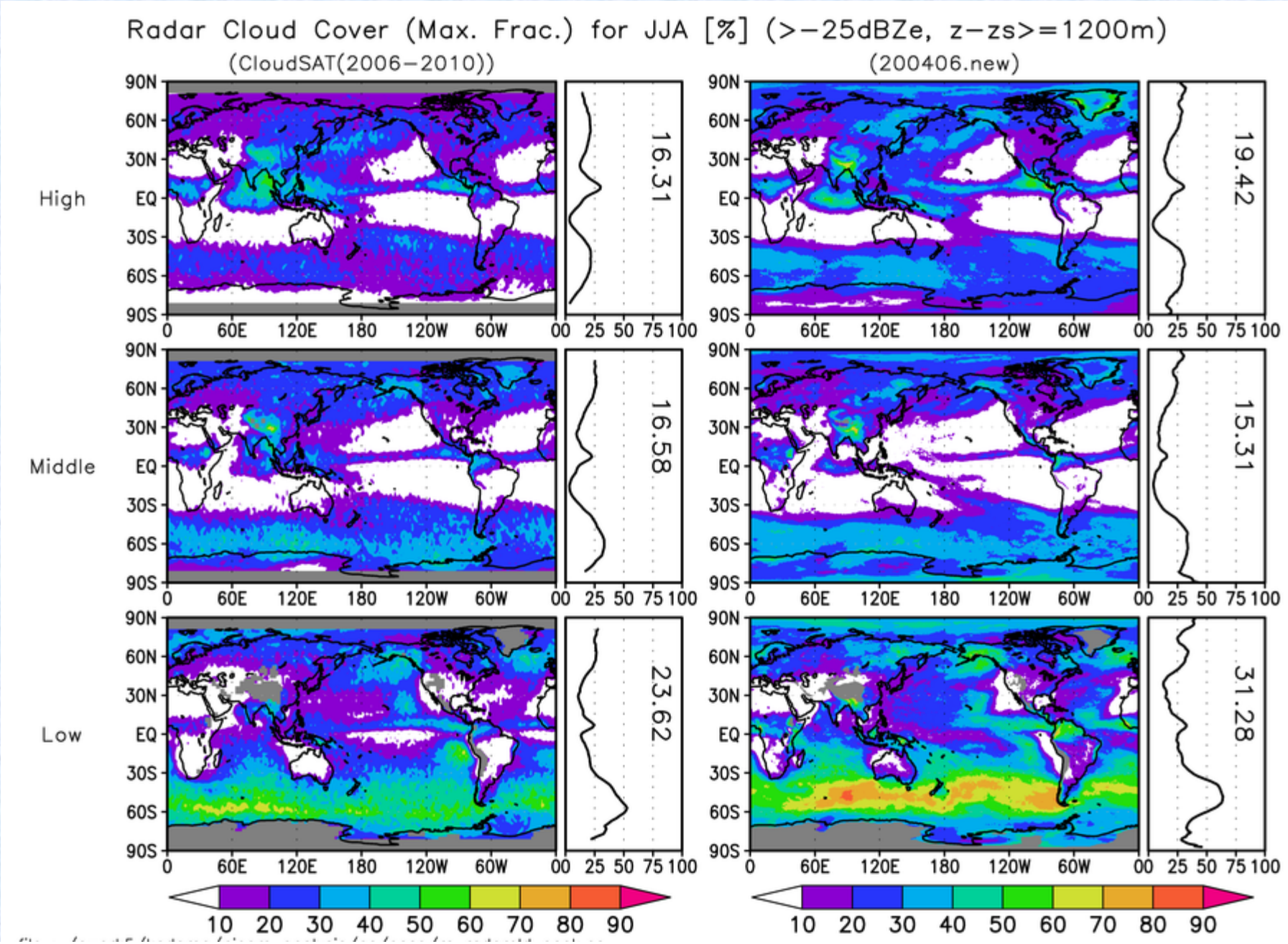
file : /cwork5/kodama/nicam_analysis/gs/cosp/ls_cfad_sr.gs
time (1) : 01jun%y 01aug%y 2006 2008
time (2) : 01jun2004 − 01aug2004
space : 210 − 270, −5 − 20

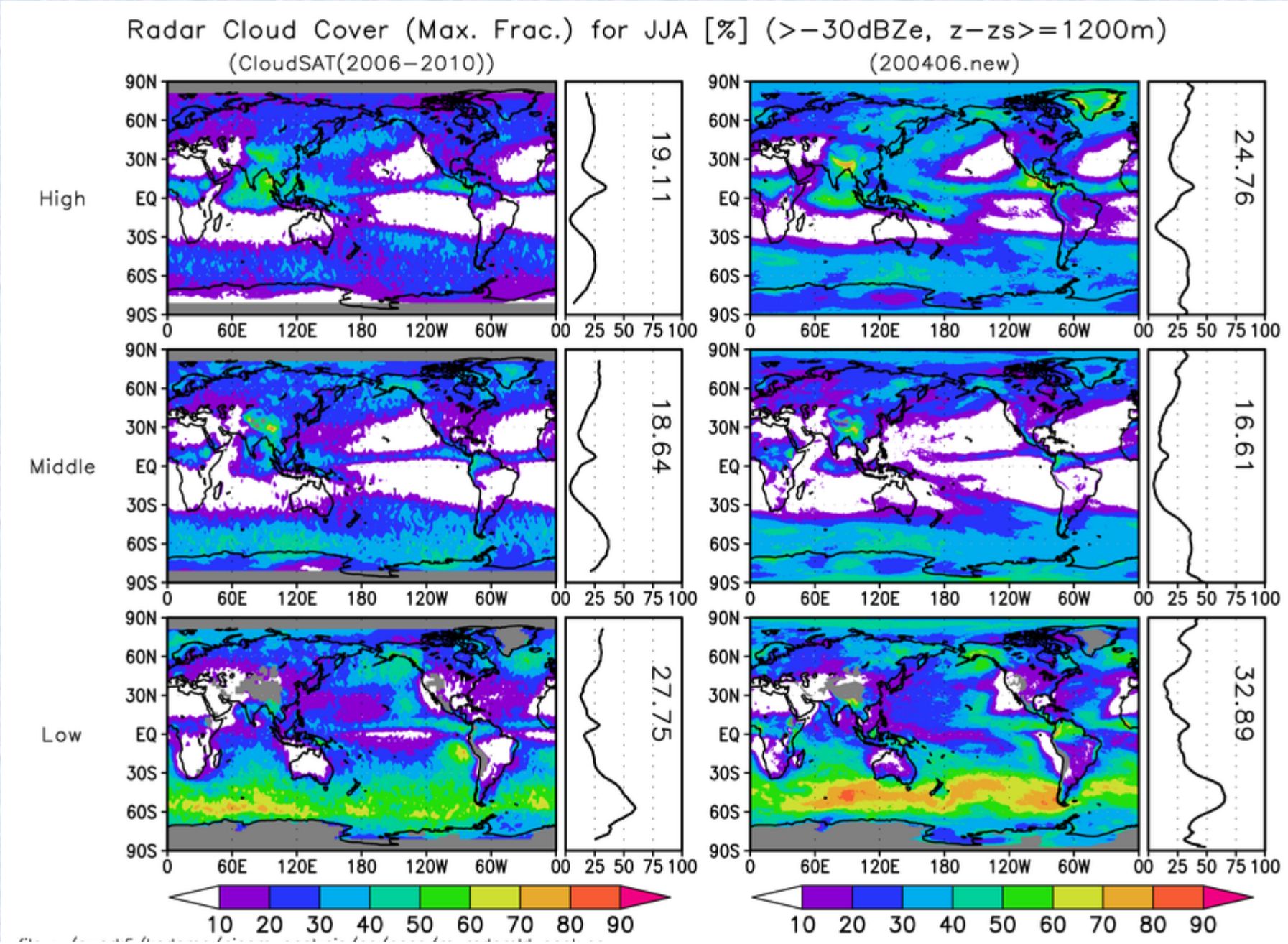

FAD [%] of Lidar Signals for JJA (North Pacific, day)
(GOCCP−clim)
(200406.new)
Freq. SR > 5 [%]
GOCCP−clim
200406.new
(Right)−(Left)
file : /cwork5/kodama/nicam_analysis/gs/cosp/ls_cfad_sr.gs
time (1) : 01jun%y 01aug%y 2006 2008
time (2) : 01jun2004 − 01aug2004
space : 160 − 220, 30 − 60


FAD [%] of Lidar Signals for JJA (California, day)
(GOCCP−clim)
(200406.new)
Freq. SR > 5 [%]
GOCCP−clim
200406.new
(Right)−(Left)
file : /cwork5/kodama/nicam_analysis/gs/cosp/ls_cfad_sr.gs
time (1) : 01jun%y 01aug%y 2006 2008
time (2) : 01jun2004 − 01aug2004
space : 220 − 250, 15 − 35

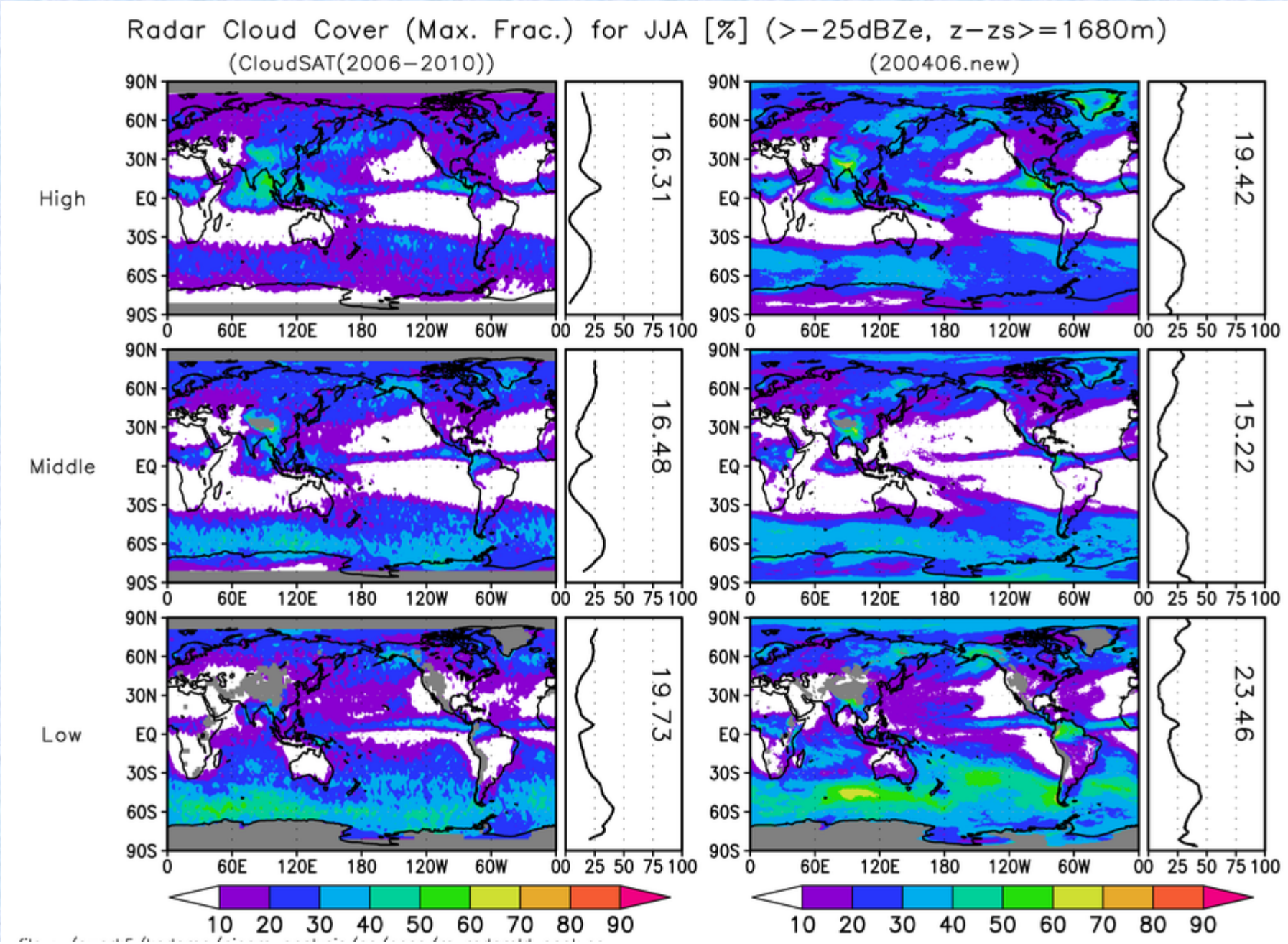
rs_radarcld_peak_m25_1200m_JJA.png



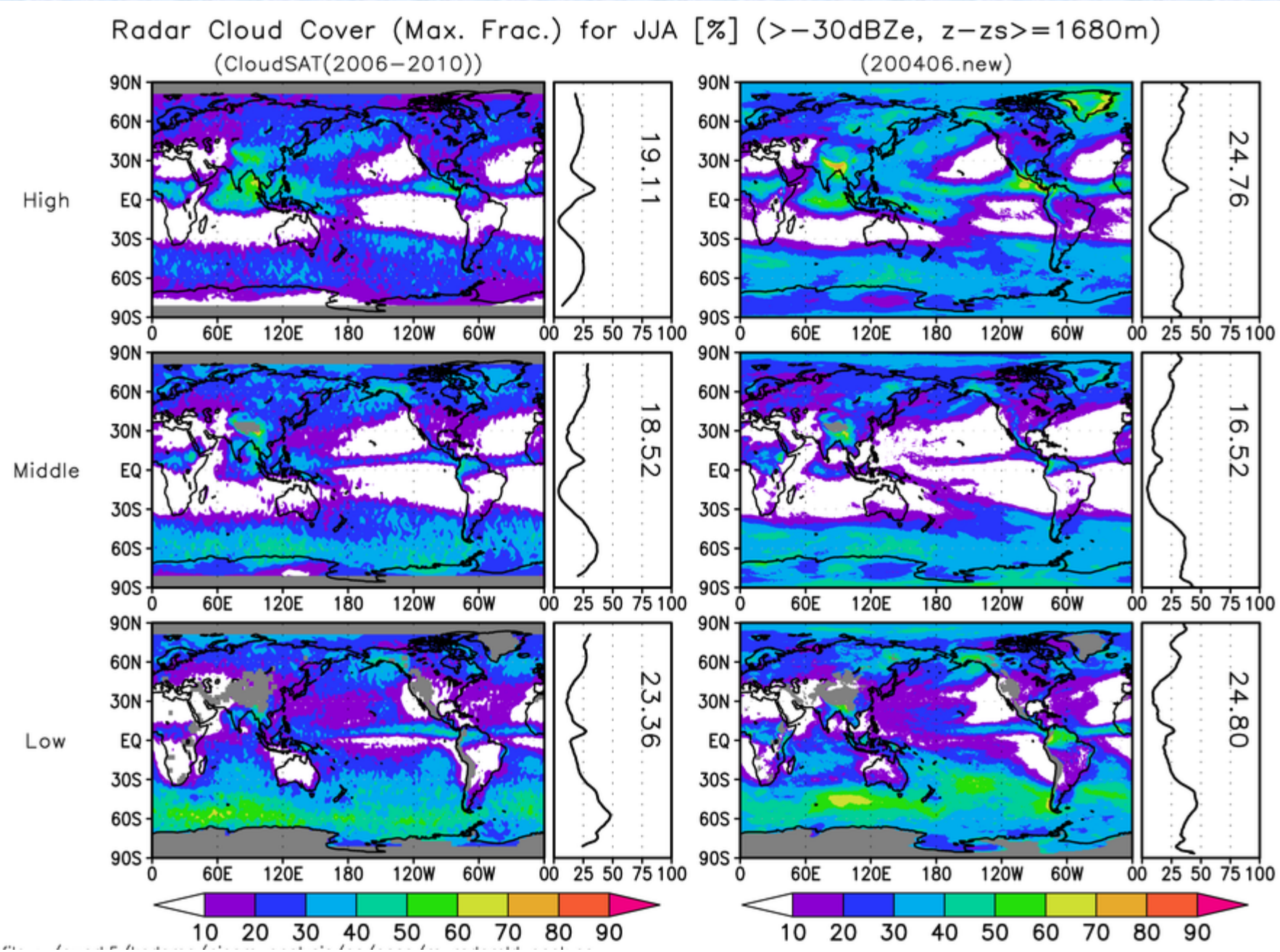
rs_radarcld_peak_m30_1200m_JJA.png



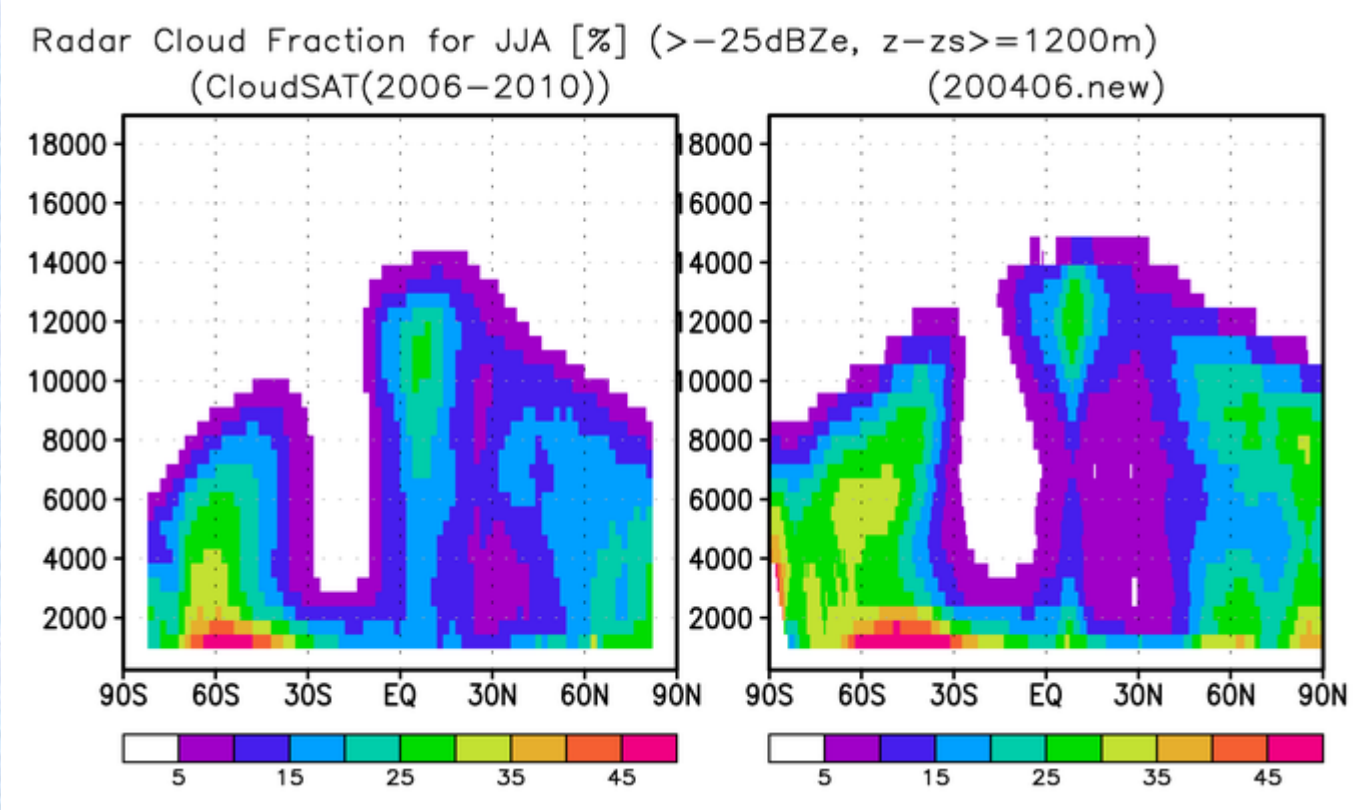
rs_radarcld_peak_m25_1680m_JJA.png



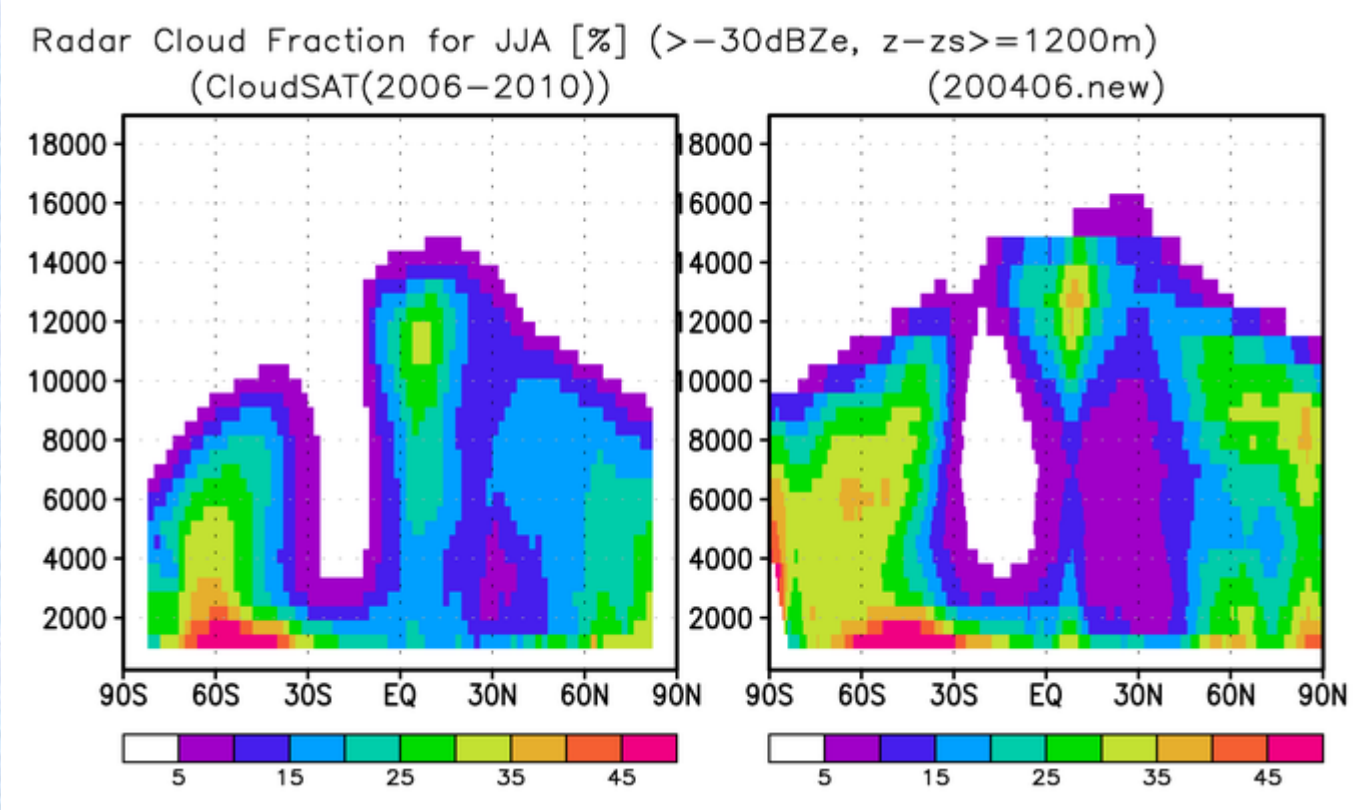
rs_radarcld_peak_m30_1680m_JJA.png



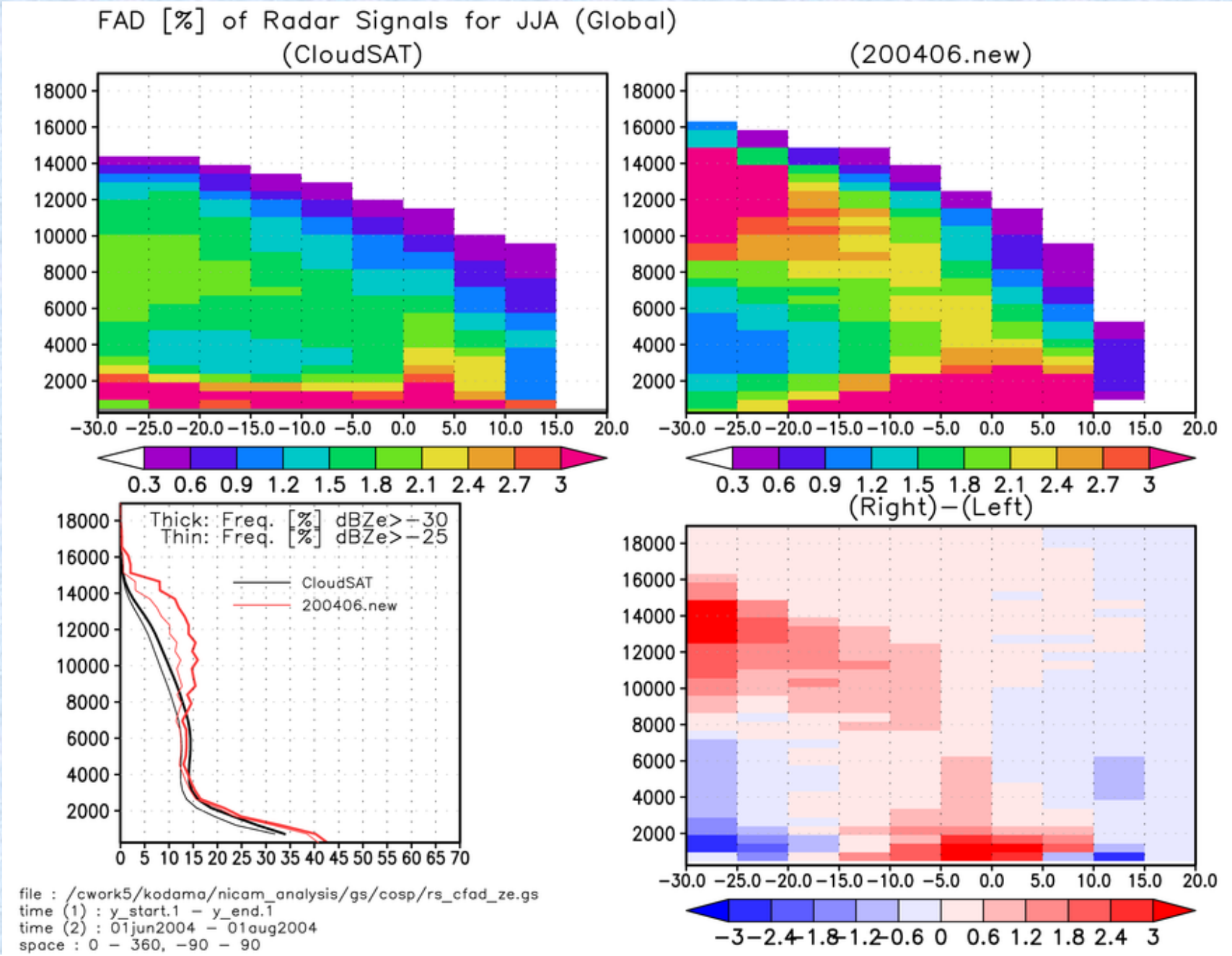
rs_radarcld_1200m_m25_JJA.png



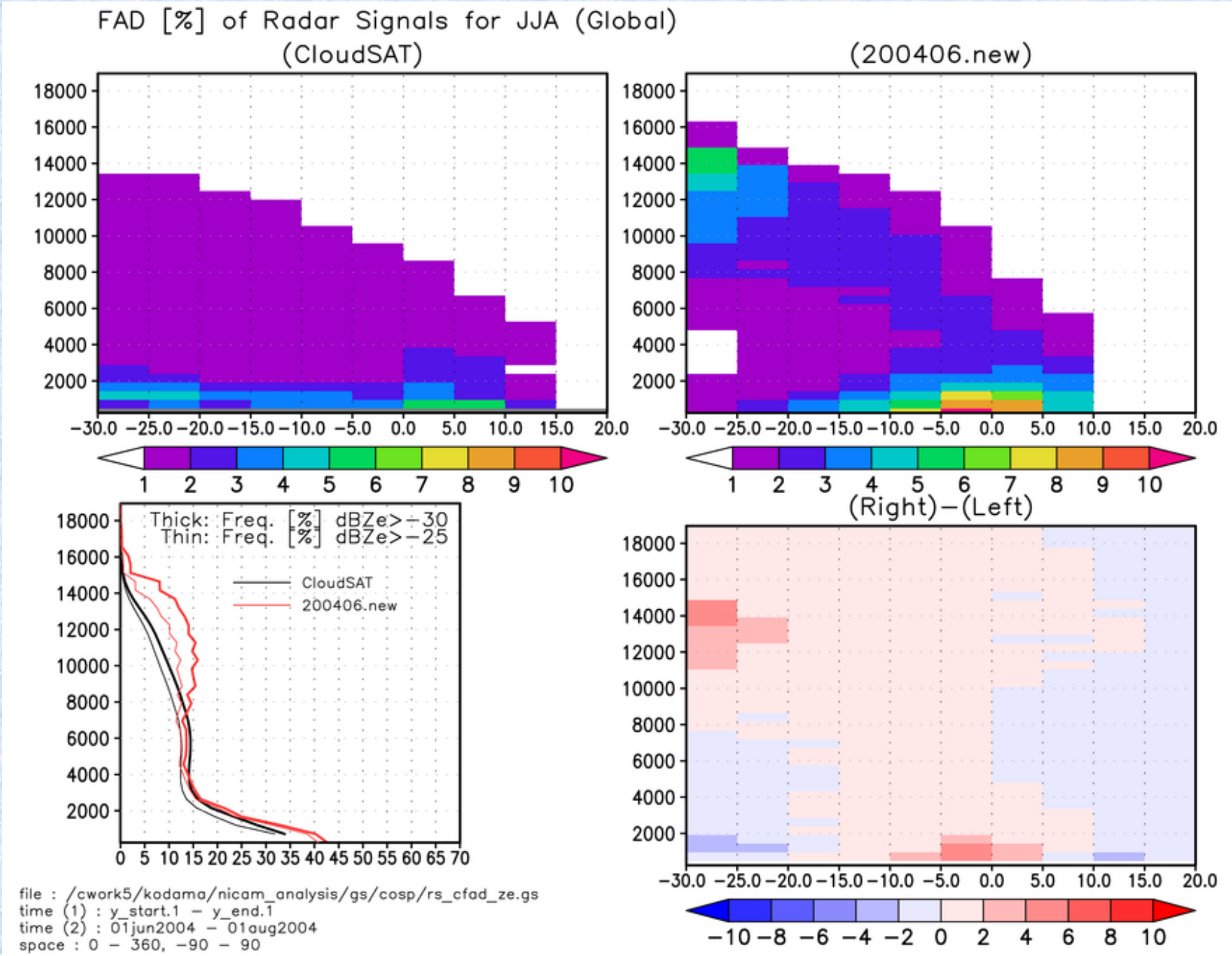
rs_radarcld_1200m_m30_JJA.png

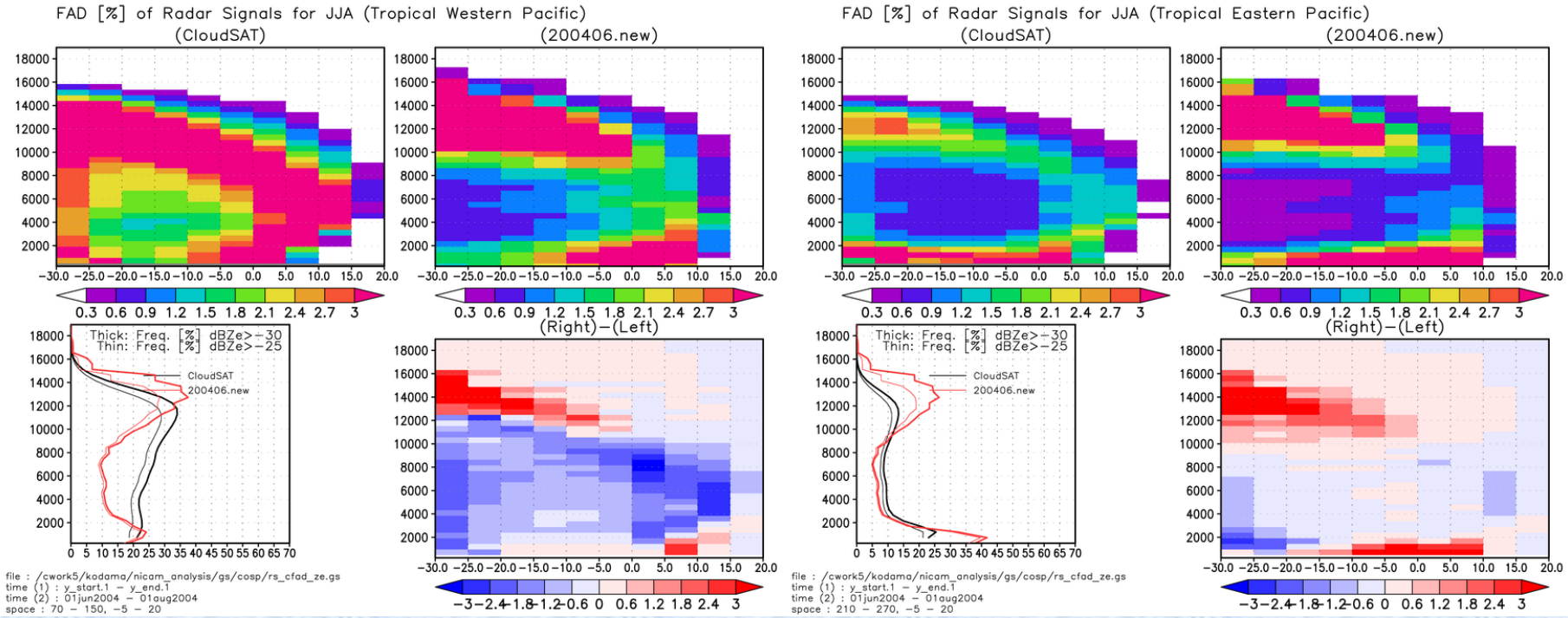


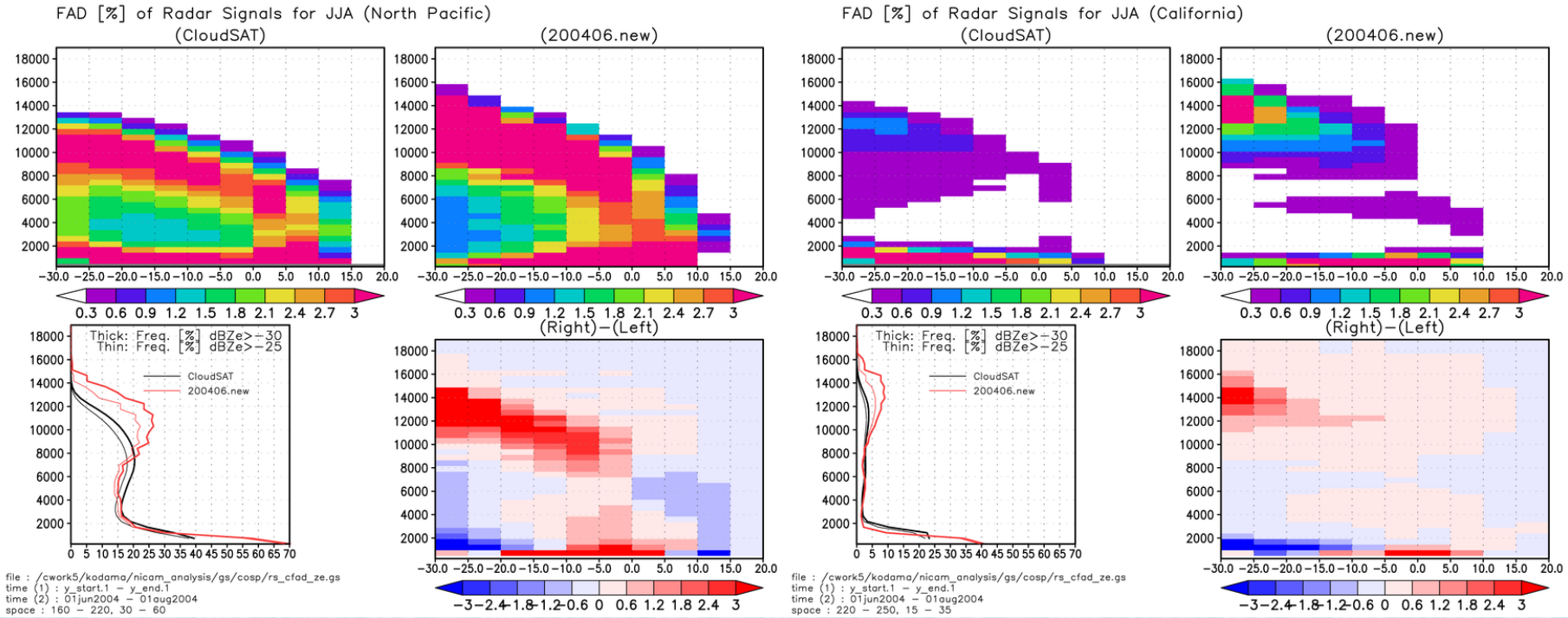
rs_cfad_ze_global_type2_JJA.png

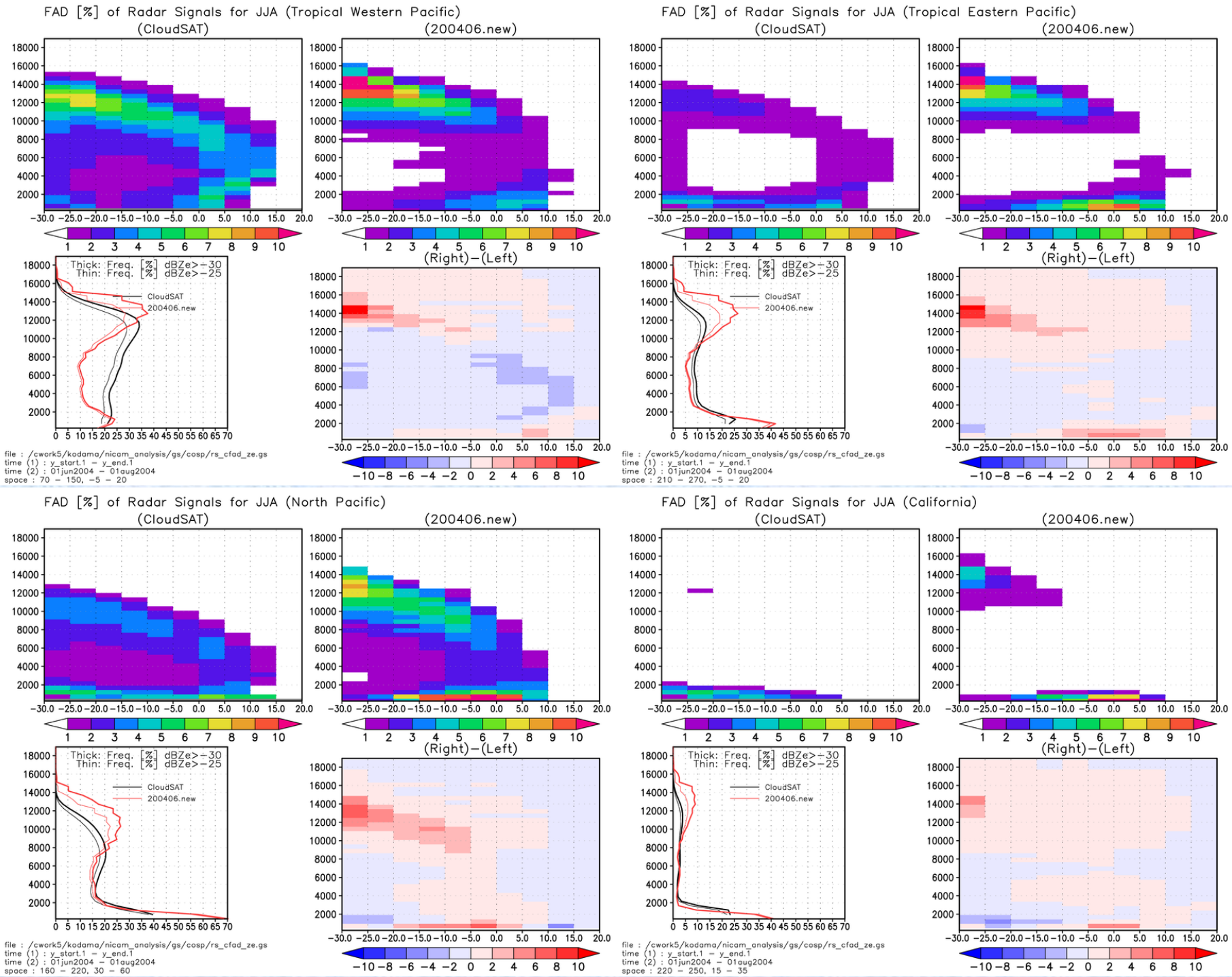


rs_cfad_ze_global_type1_JJA.png



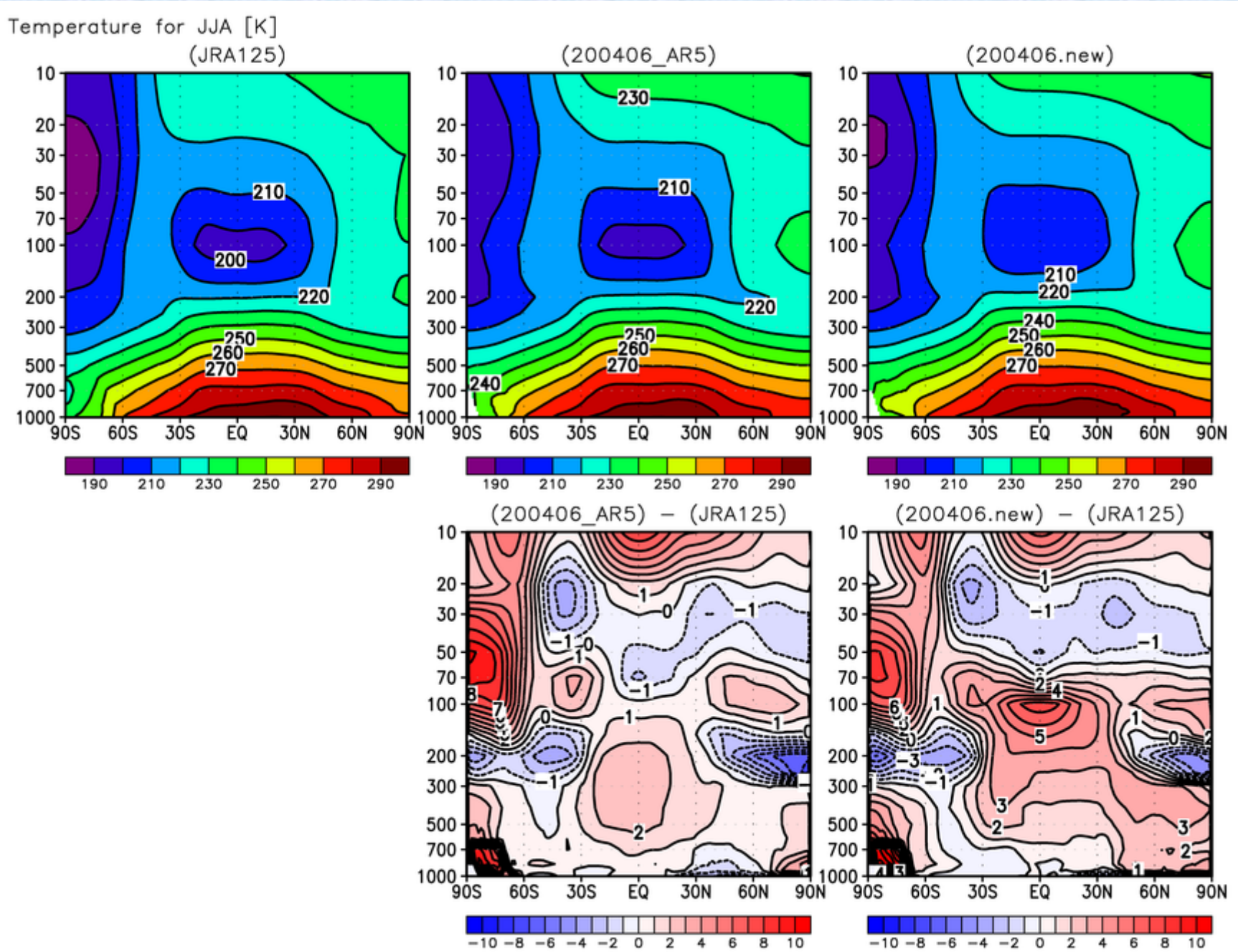

FAD [%] of Radar Signals for JJA (Tropical Western Pacific)
(CloudSAT)
(200406.new)
(Right)−(Left)
Thick: Freq. [%] dBZe>−30
Thin: Freq. [%] dBZe>−25
CloudSAT
200406.new
file : /cwork5/kodama/nicam_analysis/gs/cosp/rs_cfad_ze.gs
time (1) : y_start.1 − y_end.1
time (2) : 01jun2004 − 01aug2004
space : 70 − 150, −5 − 20
FAD [%] of Radar Signals for JJA (Tropical Eastern Pacific)
(CloudSAT)
(200406.new)
(Right)−(Left)
Thick: Freq. [%] dBZe>−30
Thin: Freq. [%] dBZe>−25
CloudSAT
200406.new
file : /cwork5/kodama/nicam_analysis/gs/cosp/rs_cfad_ze.gs
time (1) : y_start.1 − y_end.1
time (2) : 01jun2004 − 01aug2004
space : 210 − 270, −5 − 20


FAD [%] of Radar Signals for JJA (North Pacific)
(CloudSAT)
(200406.new)
(Right)−(Left)
Thick: Freq. [%] dBZe>−30
Thin: Freq. [%] dBZe>−25
CloudSAT
200406.new
file : /cwork5/kodama/nicam_analysis/gs/cosp/rs_cfad_ze.gs
time (1) : y_start.1 − y_end.1
time (2) : 01jun2004 − 01aug2004
space : 160 − 220, 30 − 60
FAD [%] of Radar Signals for JJA (California)
(CloudSAT)
(200406.new)
(Right)−(Left)
Thick: Freq. [%] dBZe>−30
Thin: Freq. [%] dBZe>−25
CloudSAT
200406.new
file : /cwork5/kodama/nicam_analysis/gs/cosp/rs_cfad_ze.gs
time (1) : y_start.1 − y_end.1
time (2) : 01jun2004 − 01aug2004
space : 220 − 250, 15 − 35

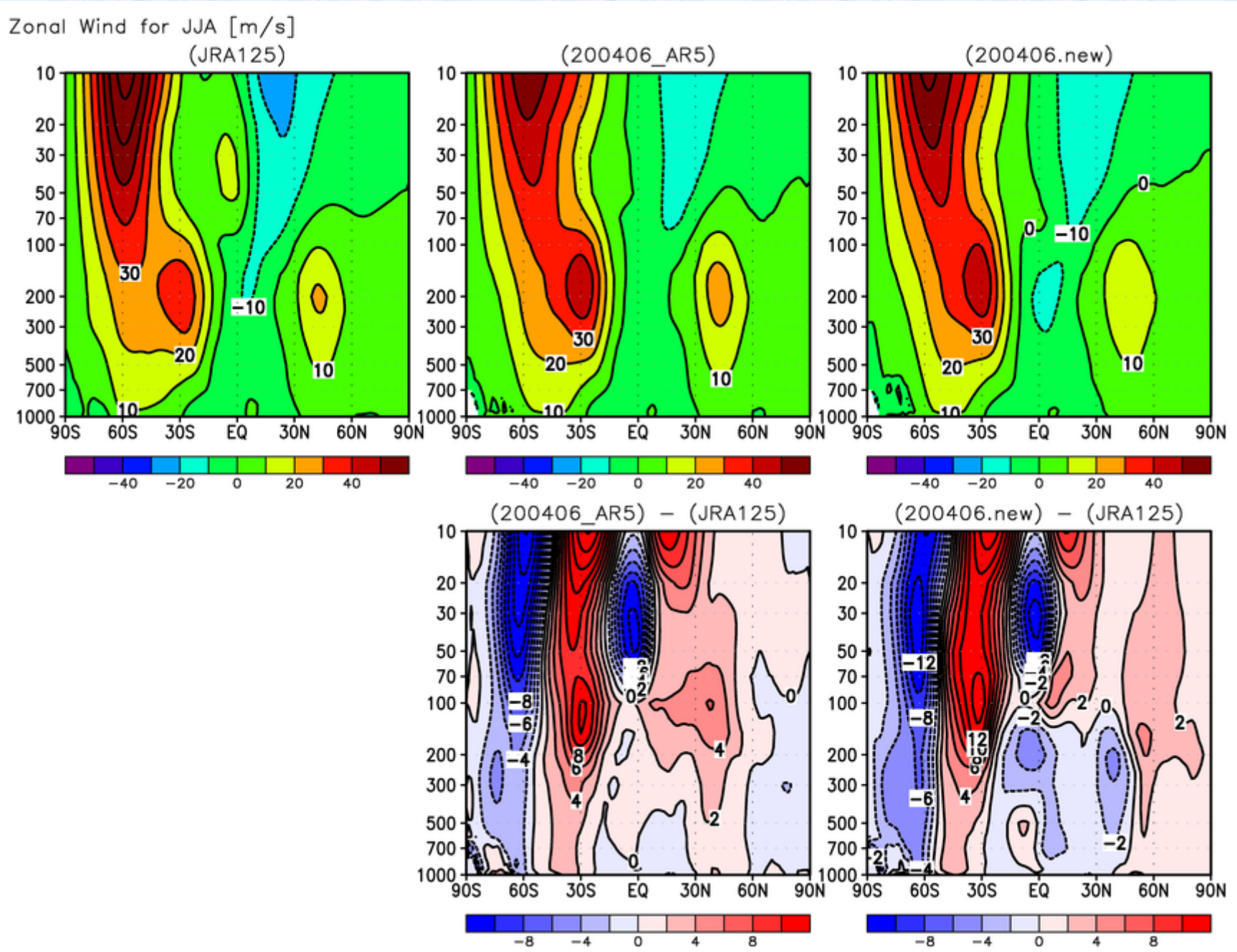

FAD [%] of Radar Signals for JJA (Tropical Western Pacific)
(CloudSAT)
(200406.new)
(Right)−(Left)
Thick: Freq. [%] dBZe>−30
Thin: Freq. [%] dBZe>−25
CloudSAT
200406.new
file : /cwork5/kodama/nicam_analysis/gs/cosp/rs_cfad_ze.gs
time (1) : y_start.1 − y_end.1
time (2) : 01jun2004 − 01aug2004
space : 70 − 150, −5 − 20
FAD [%] of Radar Signals for JJA (Tropical Eastern Pacific)
(CloudSAT)
(200406.new)
(Right)−(Left)
Thick: Freq. [%] dBZe>−30
Thin: Freq. [%] dBZe>−25
CloudSAT
200406.new
file : /cwork5/kodama/nicam_analysis/gs/cosp/rs_cfad_ze.gs
time (1) : y_start.1 − y_end.1
time (2) : 01jun2004 − 01aug2004
space : 210 − 270, −5 − 20
FAD [%] of Radar Signals for JJA (North Pacific)
(CloudSAT)
(200406.new)
(Right)−(Left)
Thick: Freq. [%] dBZe>−30
Thin: Freq. [%] dBZe>−25
CloudSAT
200406.new
file : /cwork5/kodama/nicam_analysis/gs/cosp/rs_cfad_ze.gs
time (1) : y_start.1 − y_end.1
time (2) : 01jun2004 − 01aug2004
space : 160 − 220, 30 − 60
FAD [%] of Radar Signals for JJA (California)
(CloudSAT)
(200406.new)
(Right)−(Left)
Thick: Freq. [%] dBZe>−30
Thin: Freq. [%] dBZe>−25
CloudSAT
200406.new
file : /cwork5/kodama/nicam_analysis/gs/cosp/rs_cfad_ze.gs
time (1) : y_start.1 − y_end.1
time (2) : 01jun2004 − 01aug2004
space : 220 − 250, 15 − 35

(bias, other)

Temperature

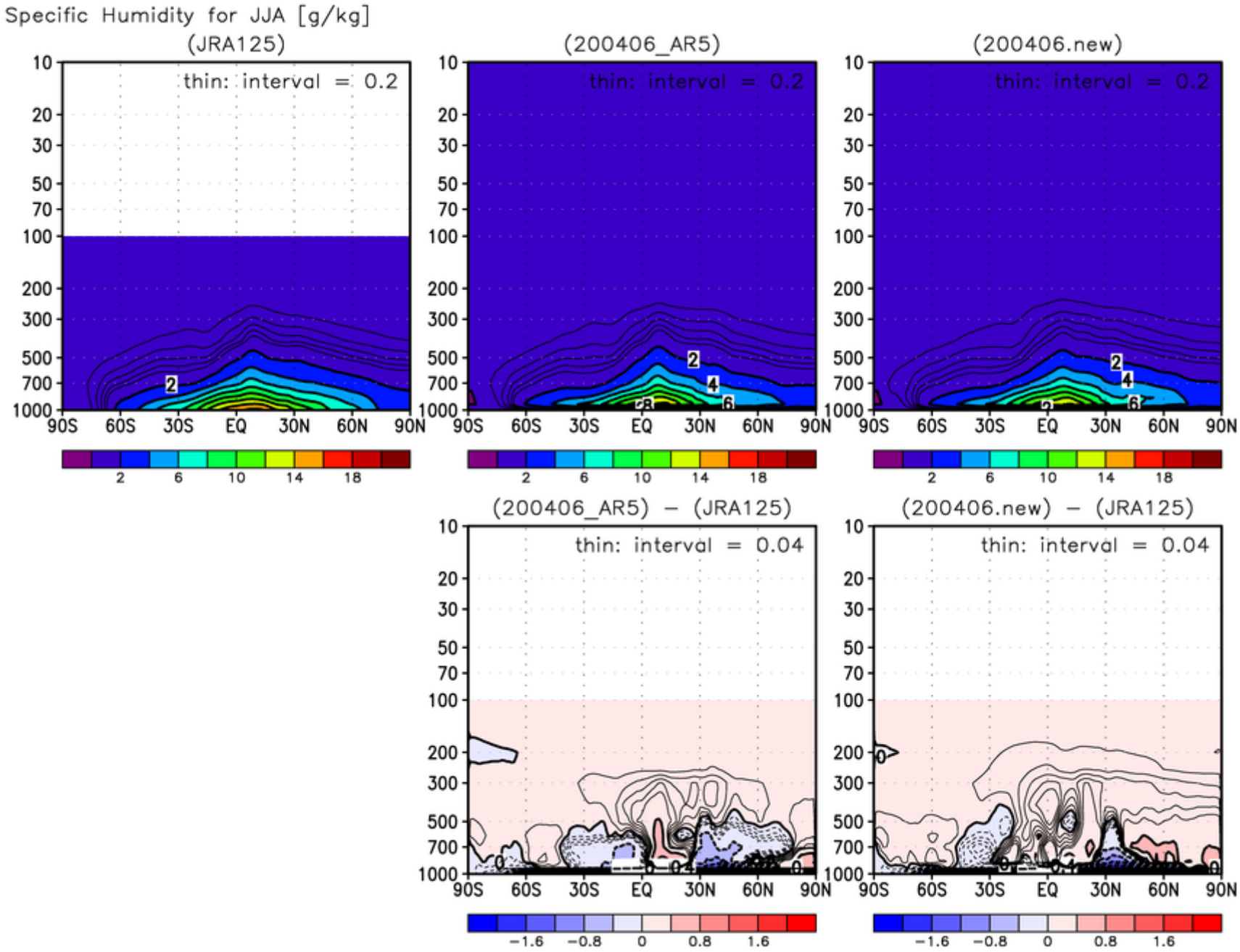


Zonal Wind


Zonal Wind for JJA [m/s]
(JRA125)
(200406_AR5)
(200406.new)
(200406_AR5) − (JRA125)
(200406.new) − (JRA125)
10
20
30
50
70
100
200
300
500
700
1000
90S
60S
30S
EQ
30N
60N
90N
−40
−20
0
20
40
−8
−4
0
4
8

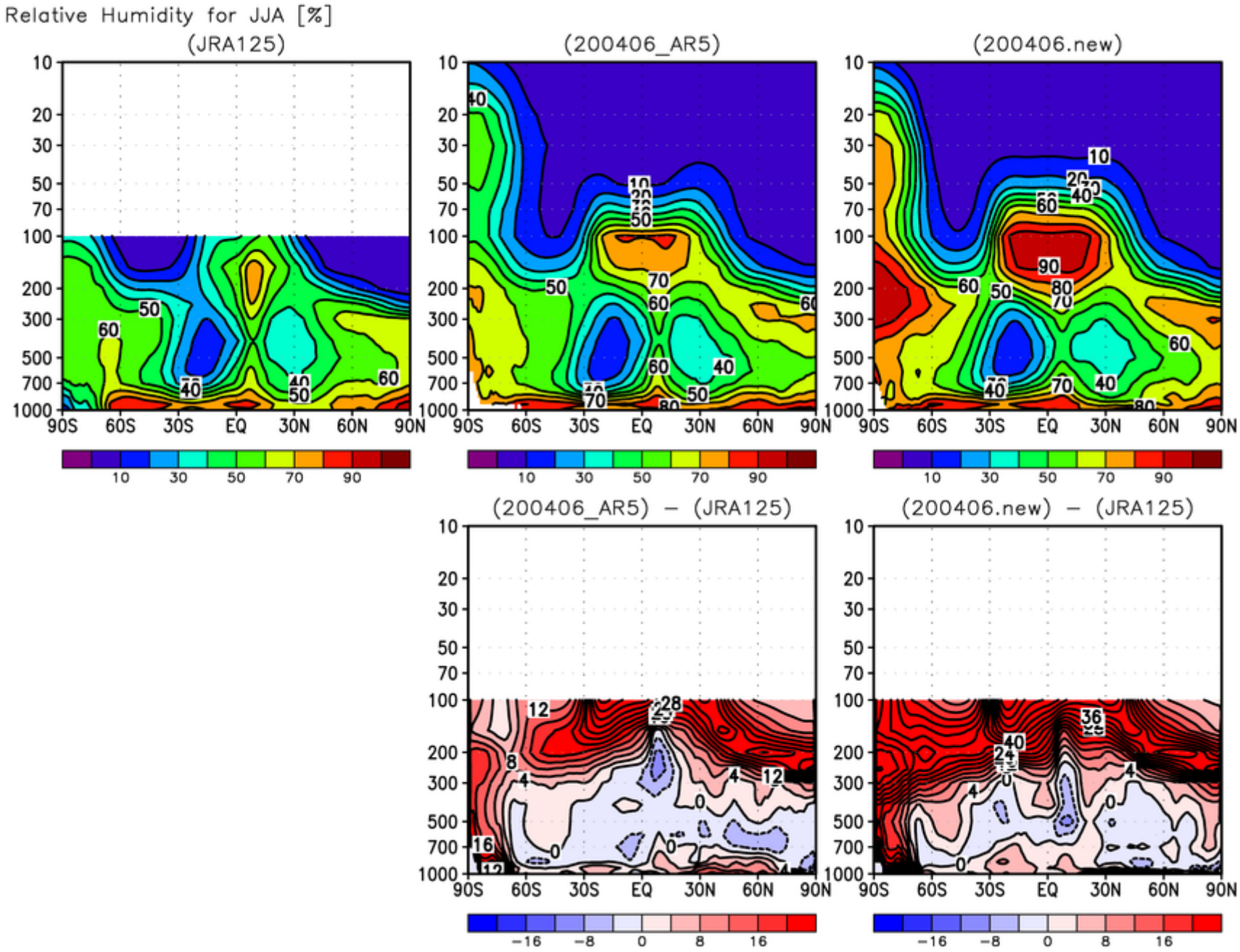
Specific Humidity (JJA)

TODO：他の再解析とも比較すべき

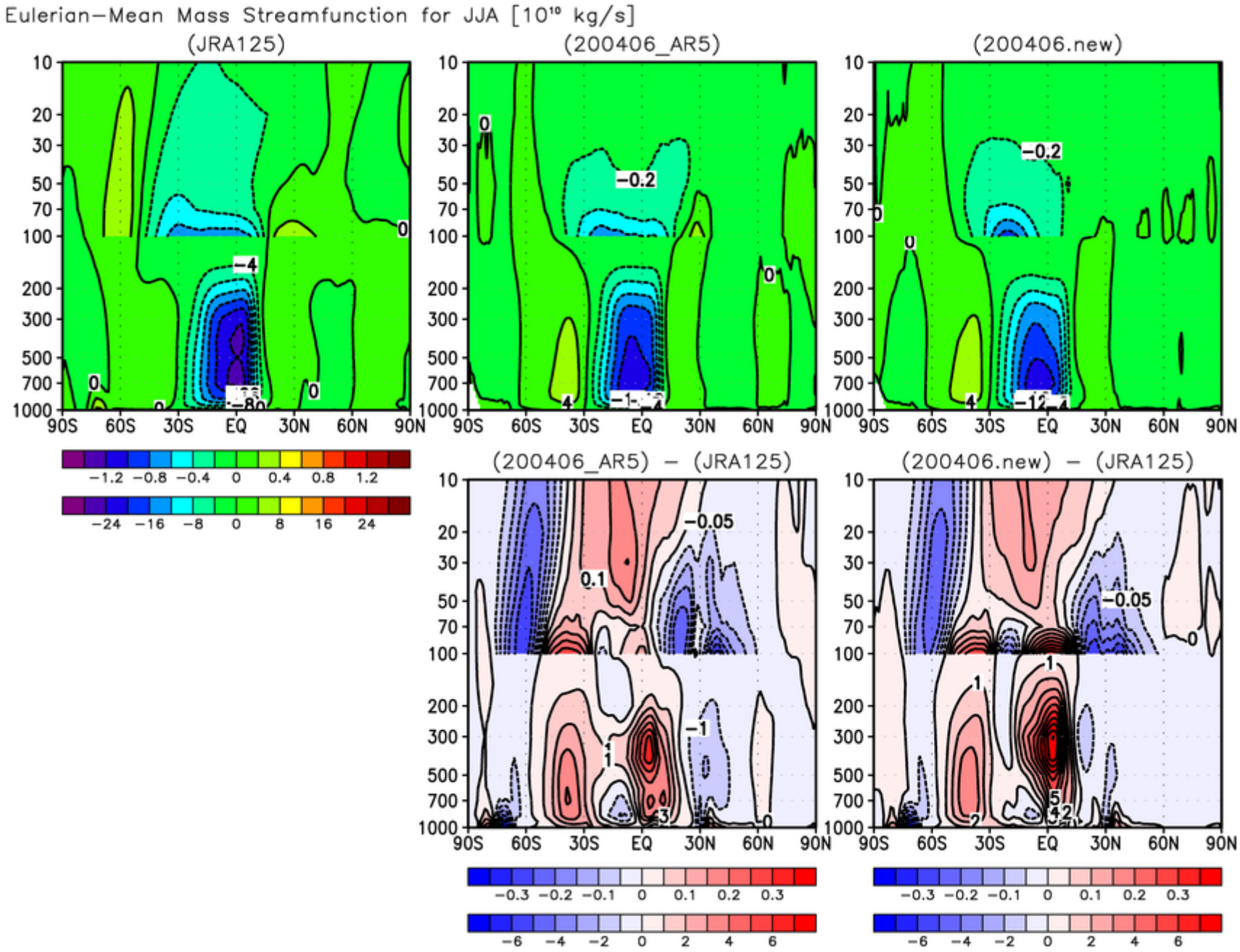


Relative Humidity (JJA)

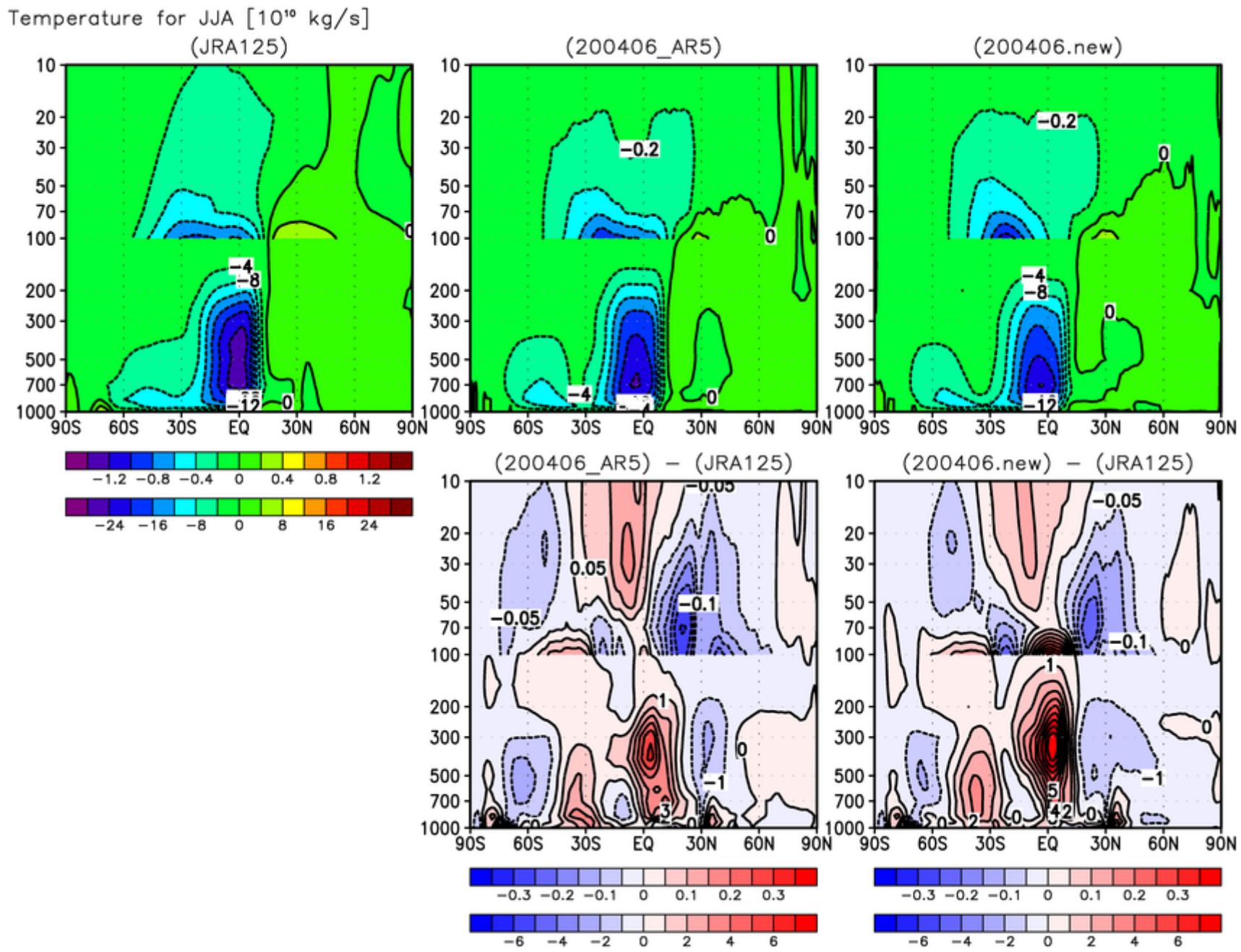
TODO：他の再解析とも比較すべき



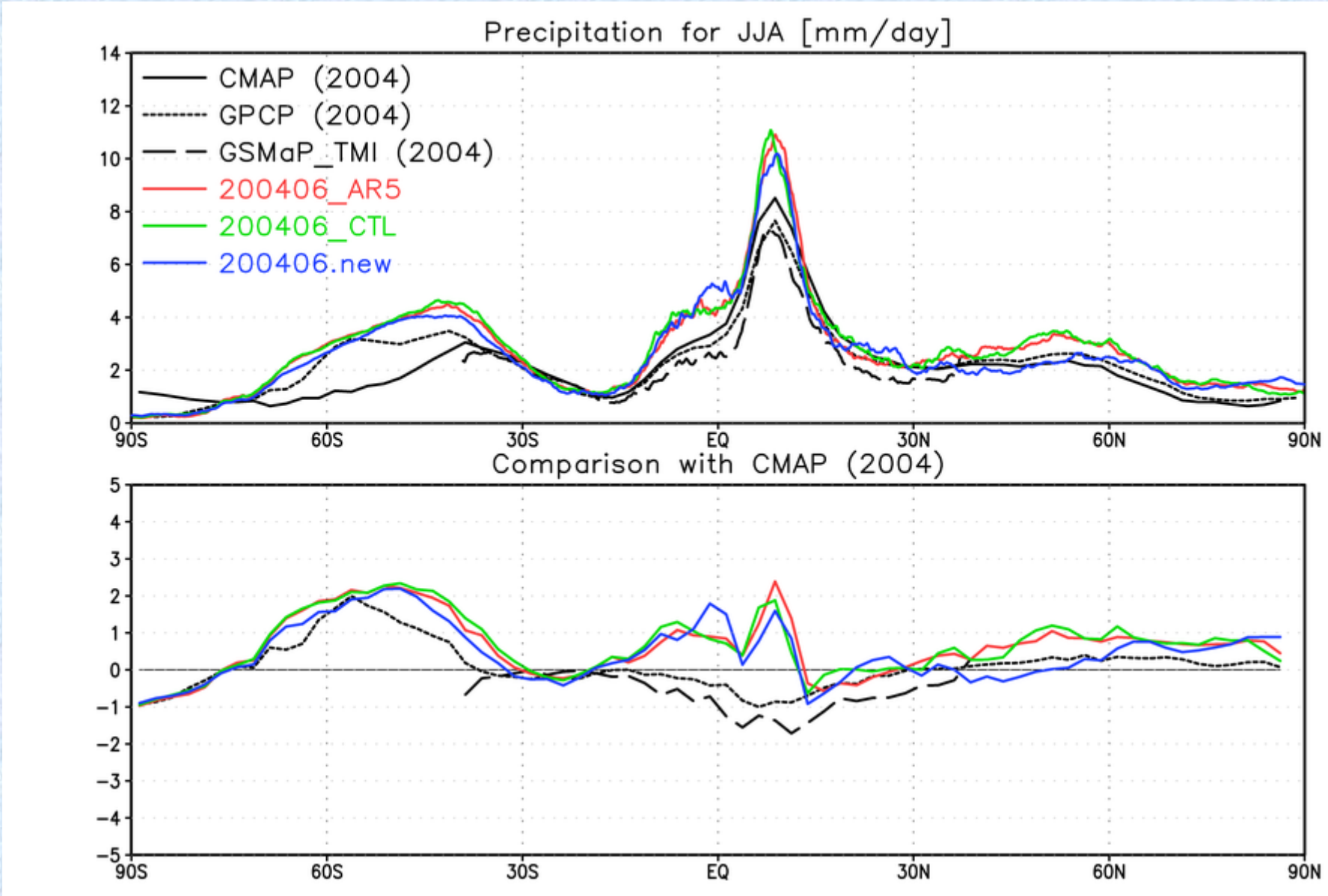
Eulerian Circulation



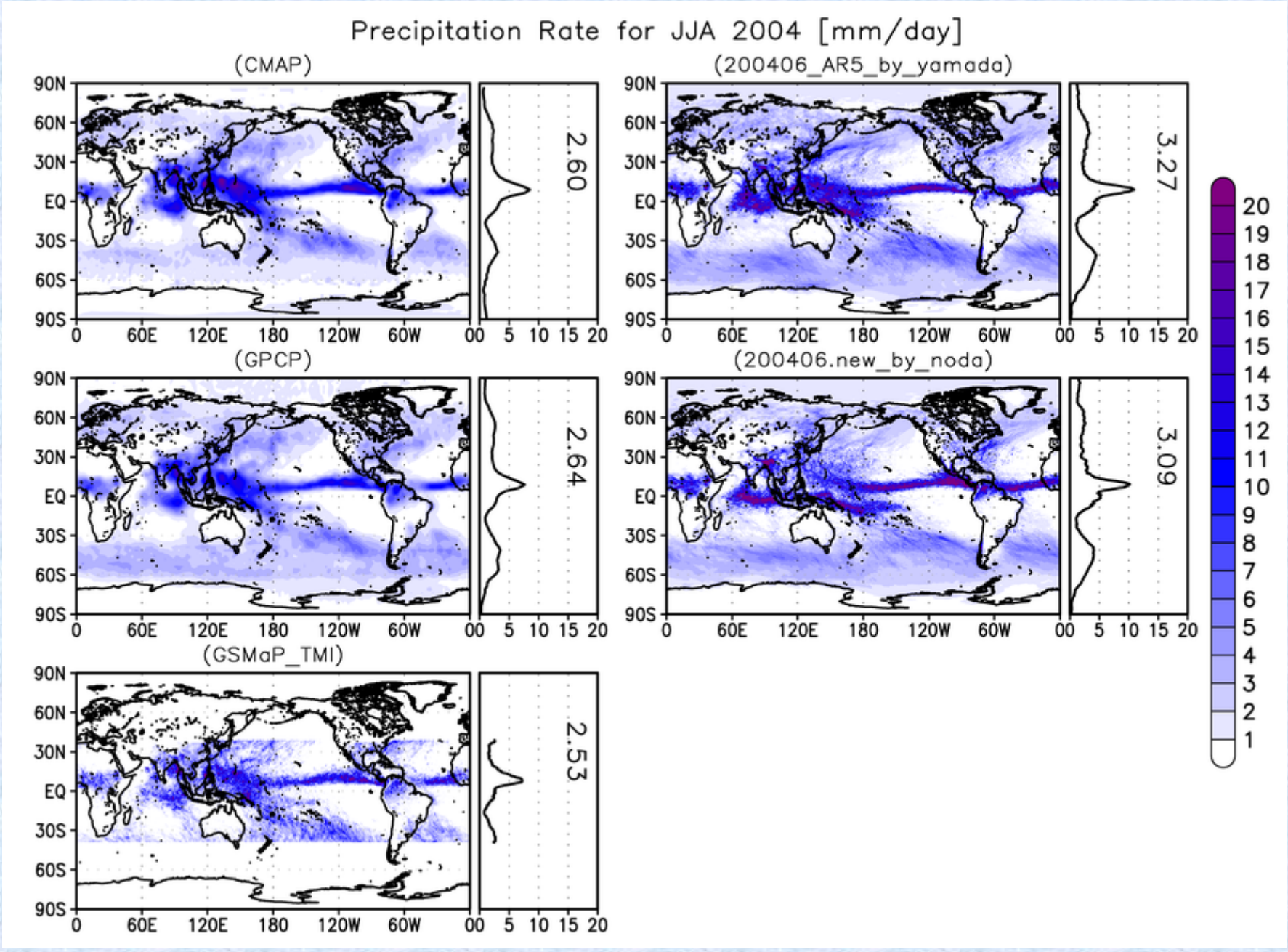
MIM Circulation



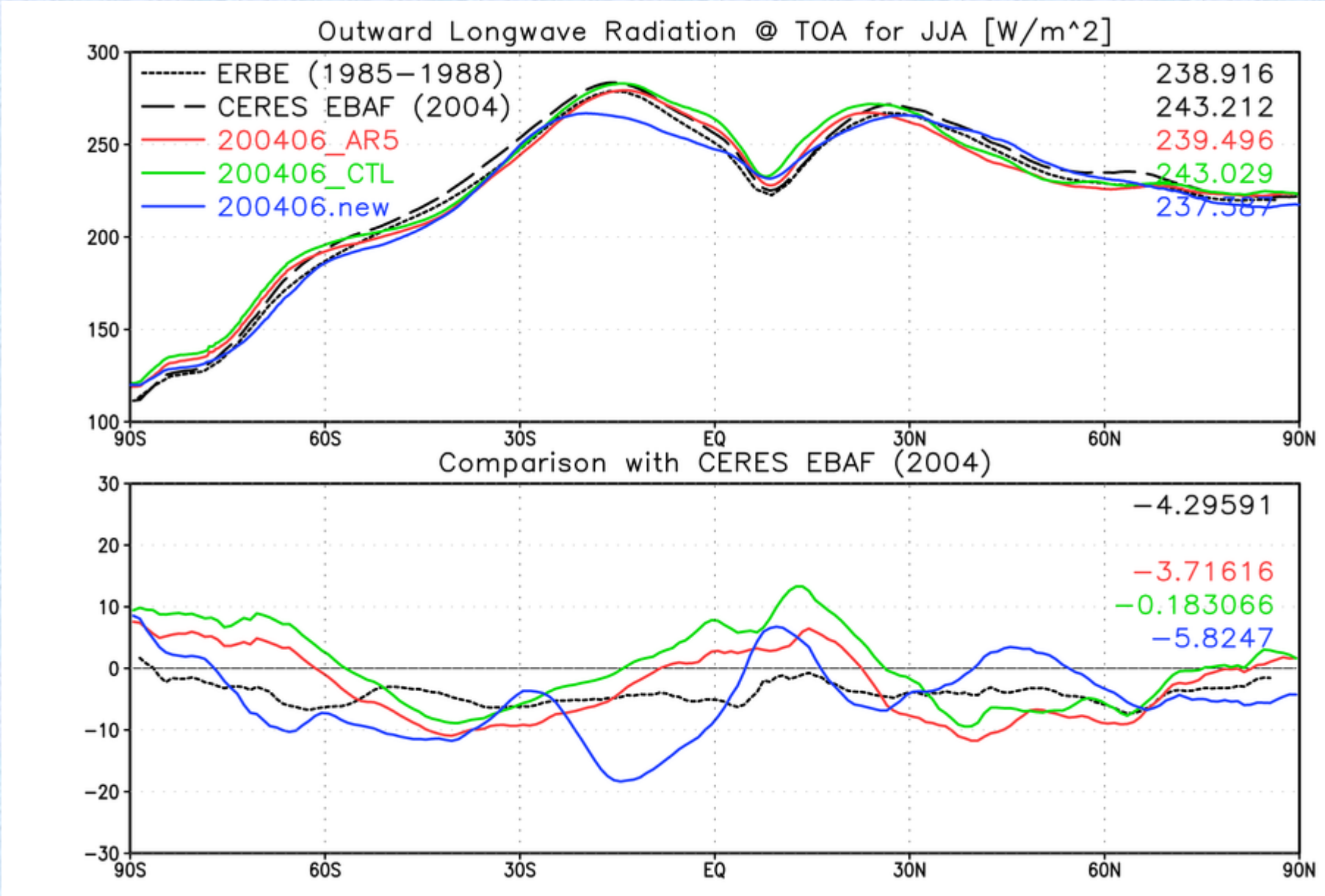
Zonal Mean Precipitation



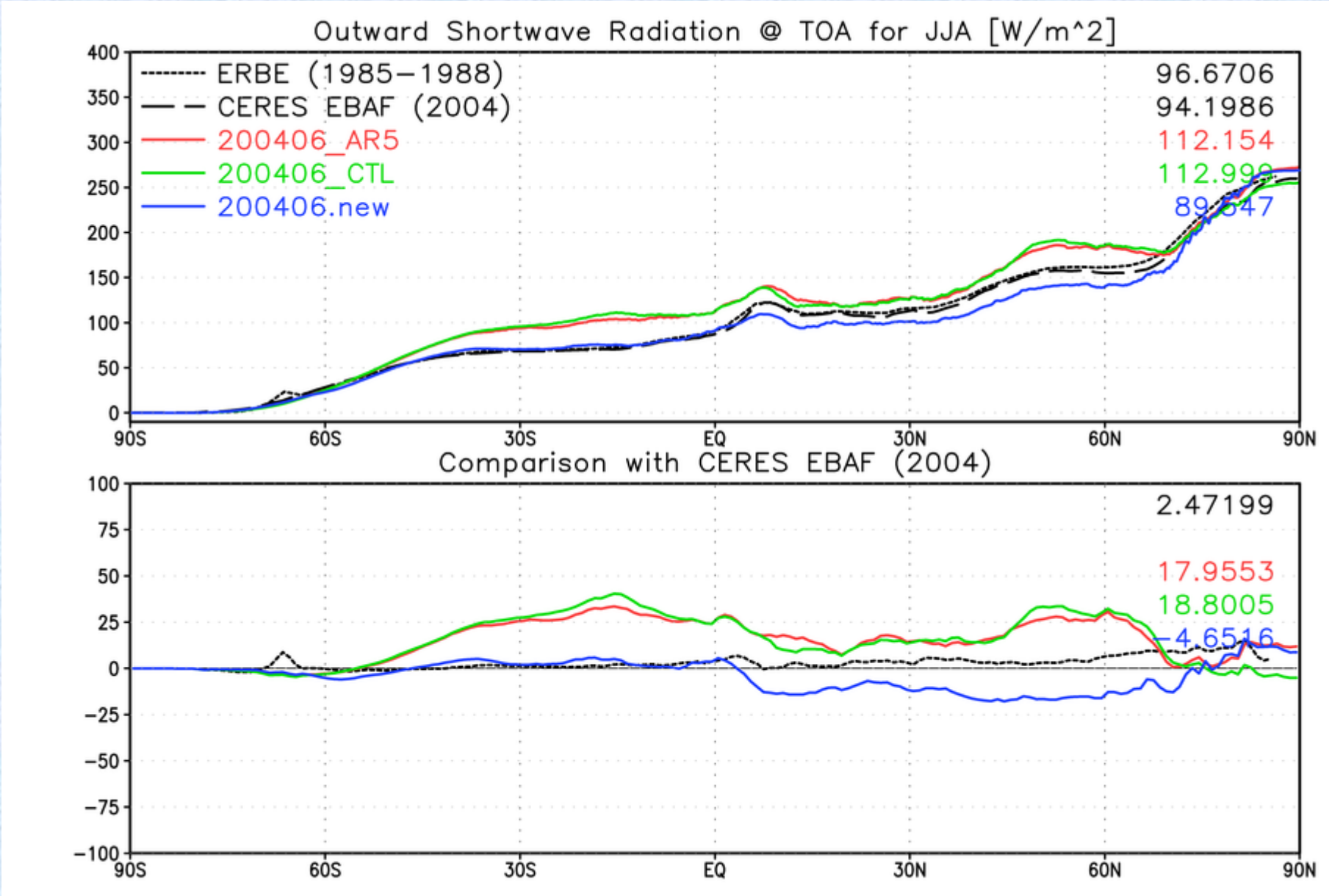
Precipitation



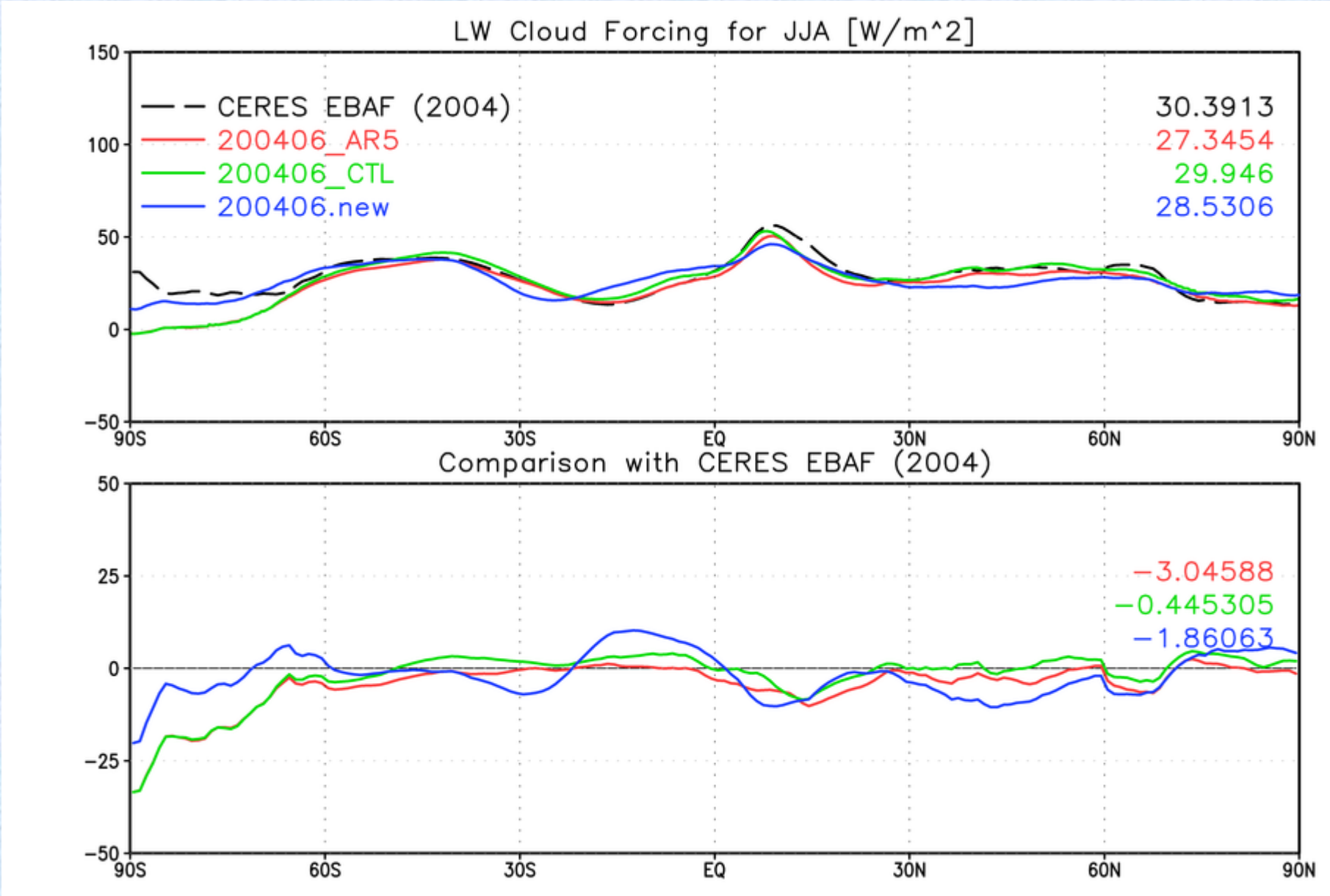
OLR (JJA)


Outward Longwave Radiation @ TOA for JJA [W/m^2]
ERBE (1985–1988)
CERES EBAF (2004)
200406_AR5
200406_CTL
200406.new
238.916
243.212
239.496
243.029
237.387
300
250
200
150
100
90S
60S
30S
EQ
30N
60N
90N
Comparison with CERES EBAF (2004)
−4.29591
−3.71616
−0.183066
−5.8247
30
20
10
0
−10
−20
−30

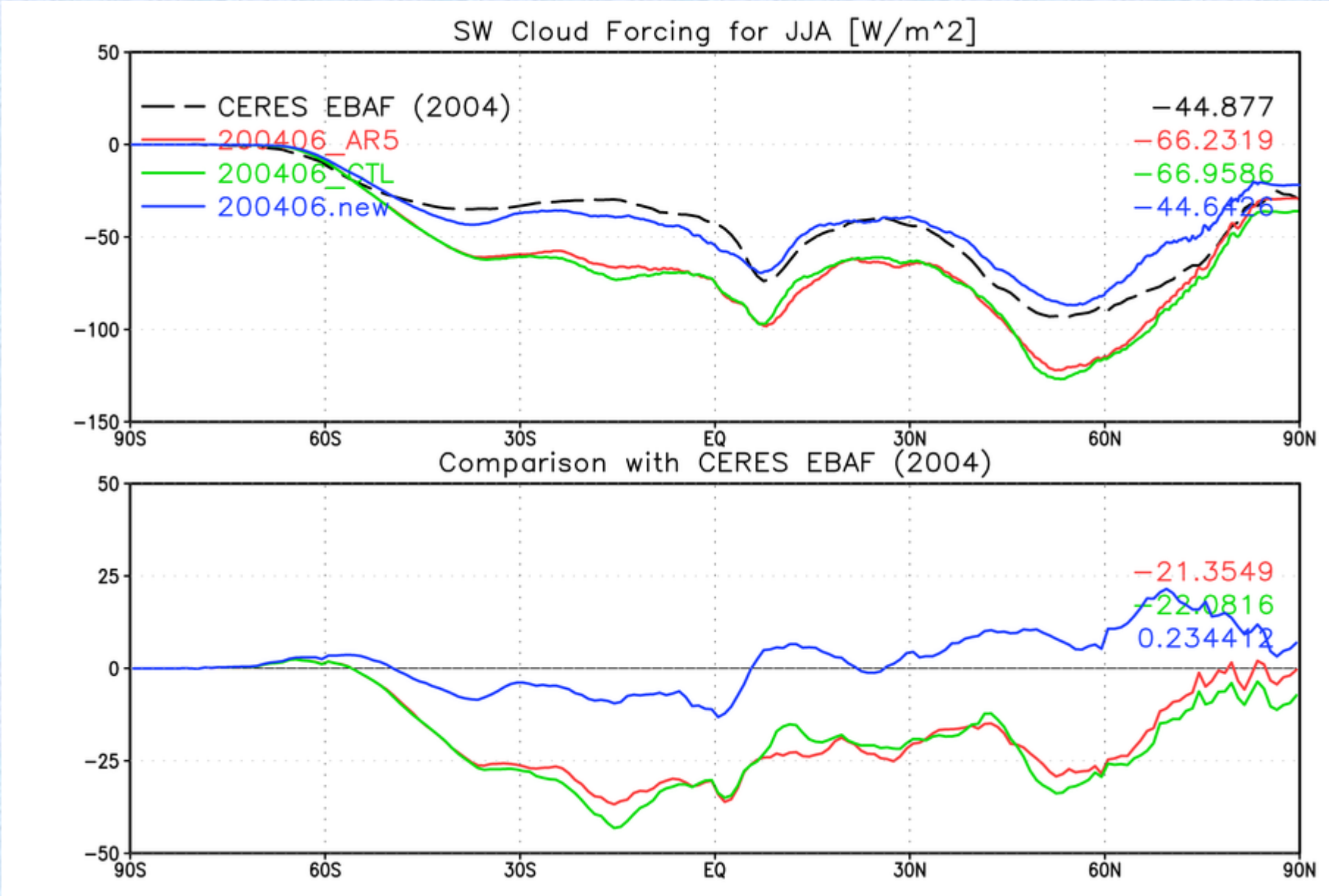
OSR (JJA)


Outward Shortwave Radiation @ TOA for JJA [W/m^2]
ERBE (1985–1988)
CERES EBAF (2004)
200406_AR5
200406_CTL
200406.new
96.6706
94.1986
112.154
112.998
89.547
400
350
300
250
200
150
100
50
0
90S
60S
30S
EQ
30N
60N
90N
Comparison with CERES EBAF (2004)
2.47199
17.9553
18.8005
-4.6516
100
75
50
25
0
−25
−50
−75
−100

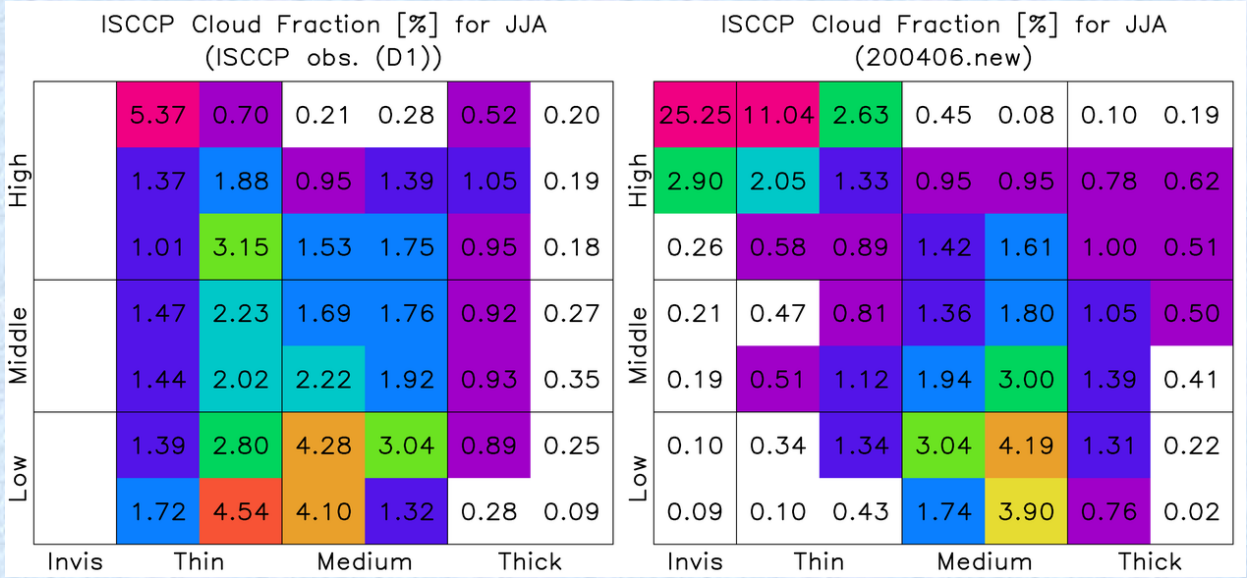
Longwave Cloud Forcing (JJA)

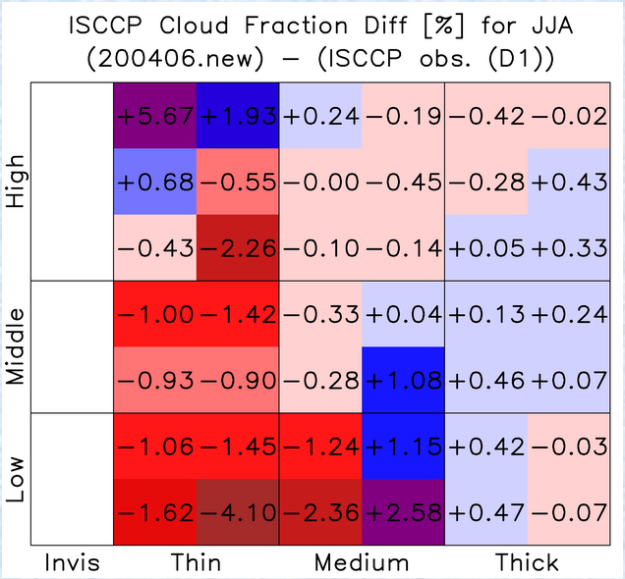


Shortwave Cloud Forcing (JJA)



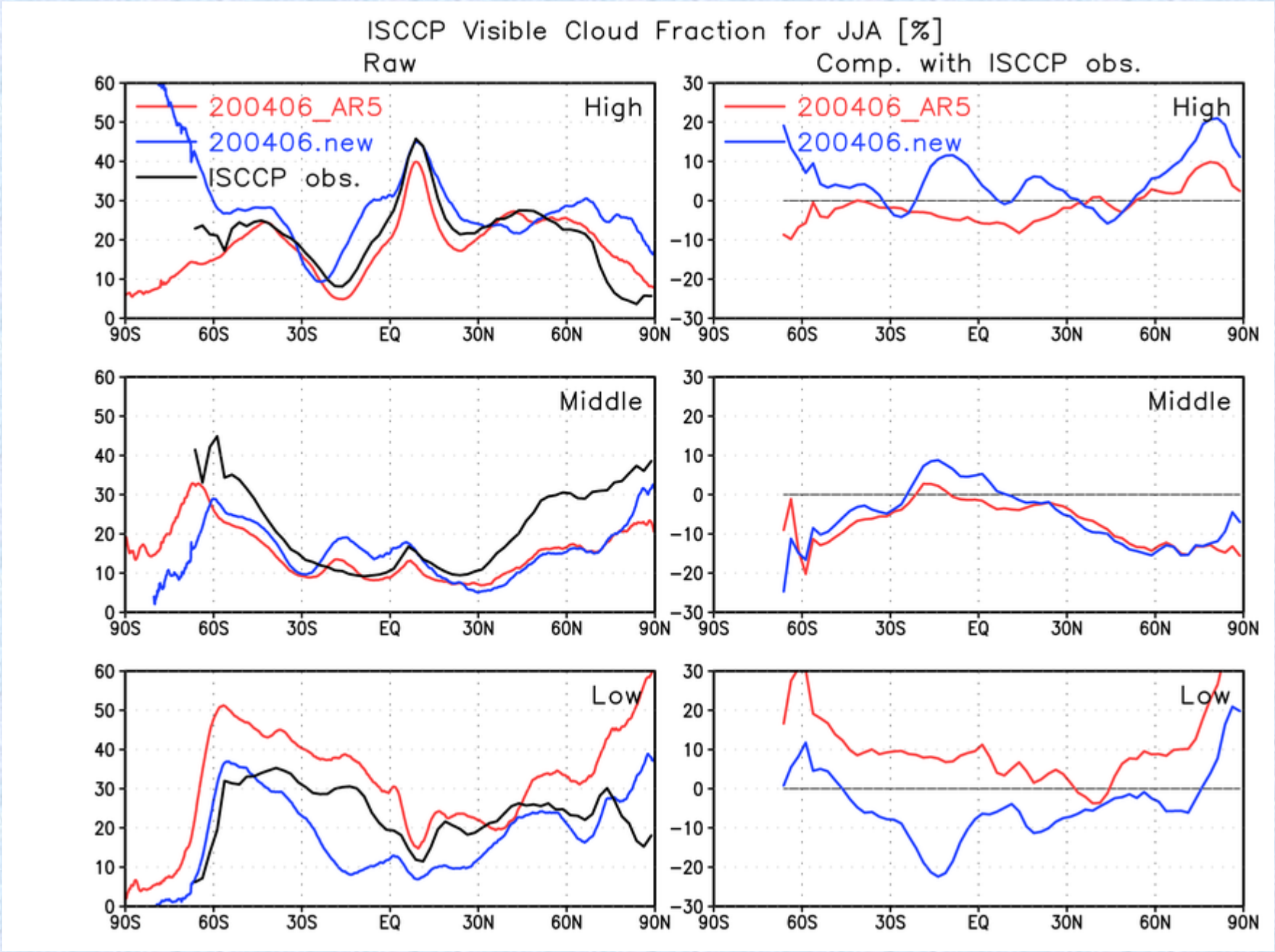
isccp_matrix_AR5_7x7_JJA.png



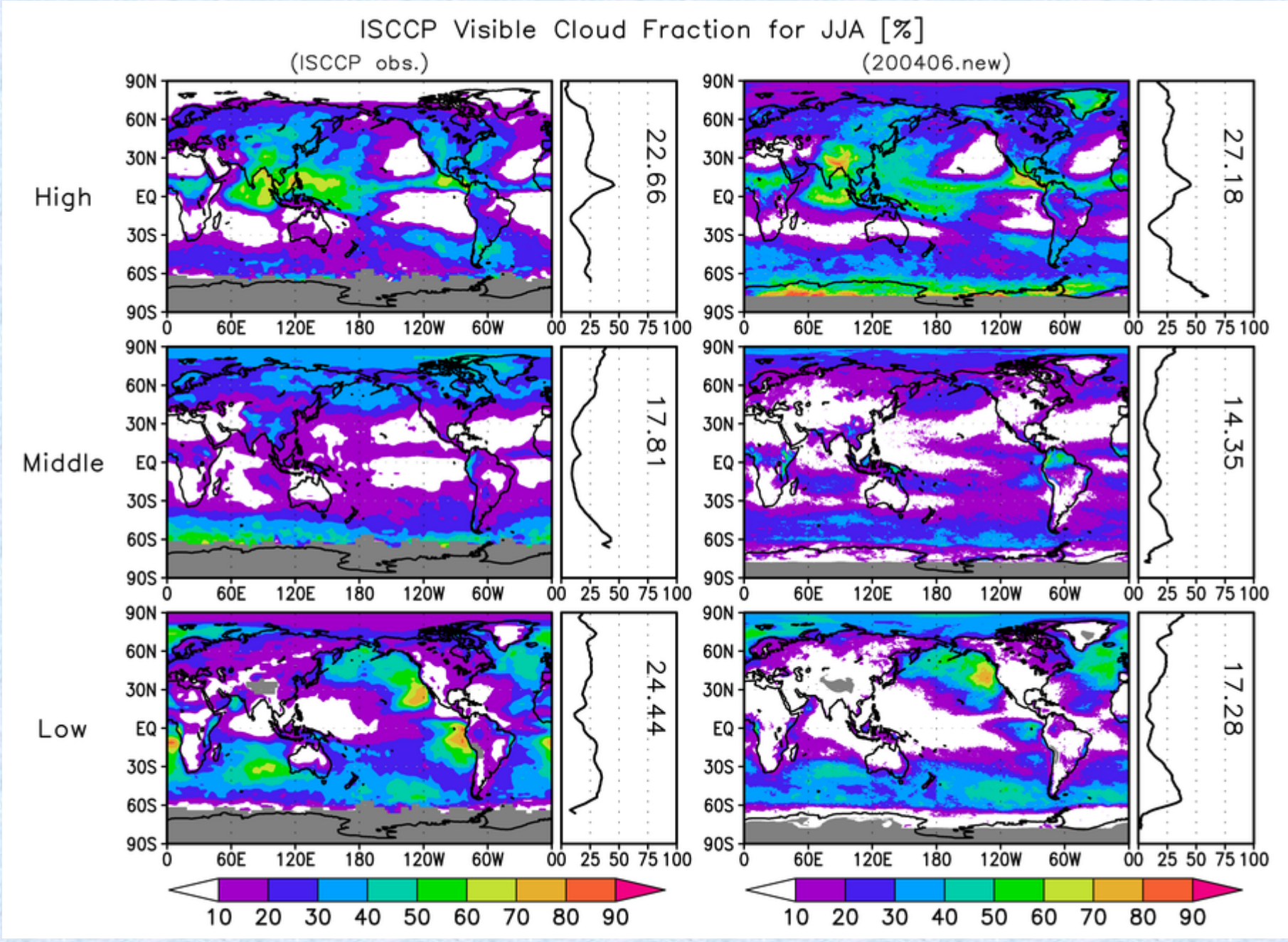


Zonal Mean ISCCP Visible Cloud Fraction

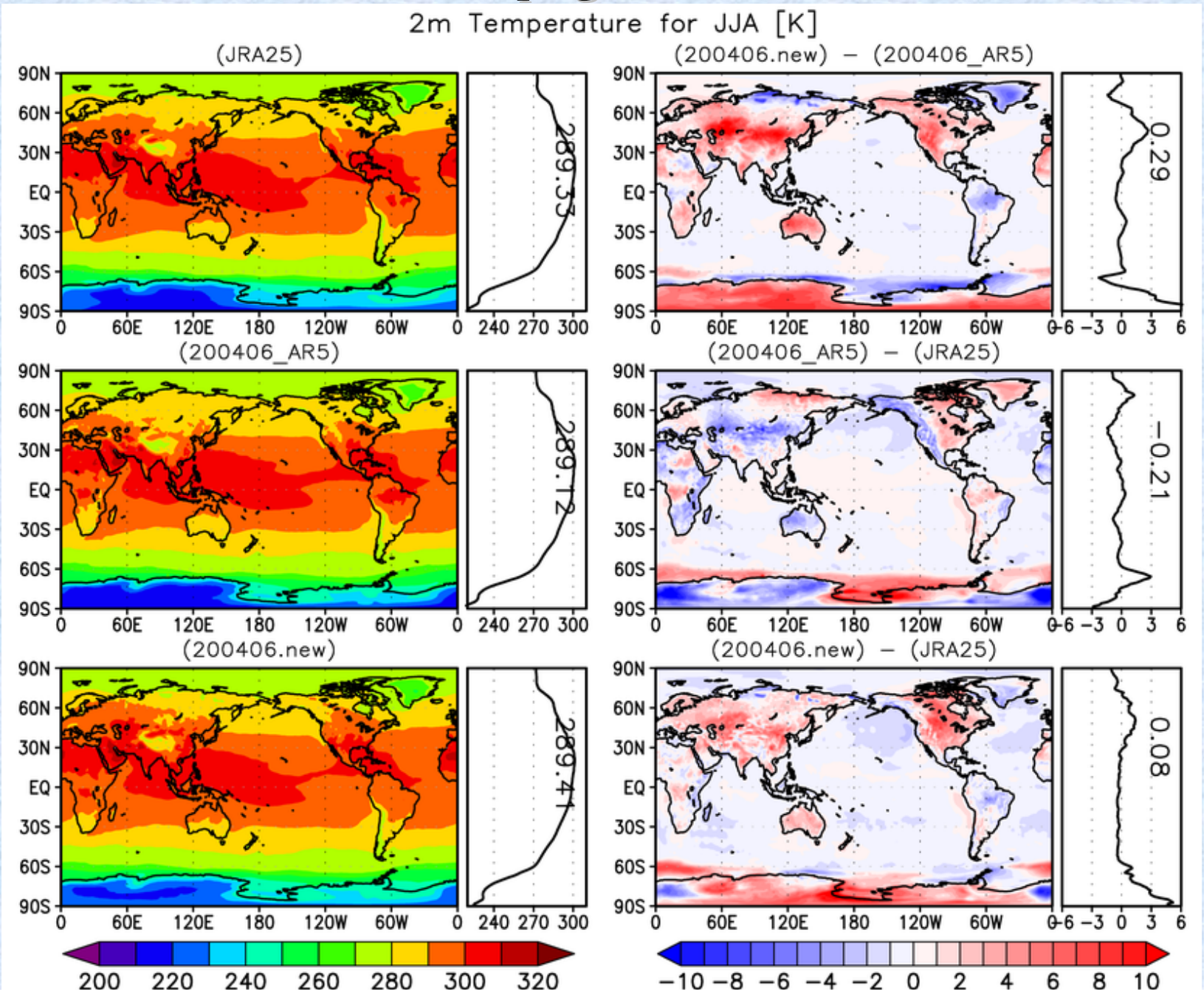
他の図と地形の扱いが違うので注



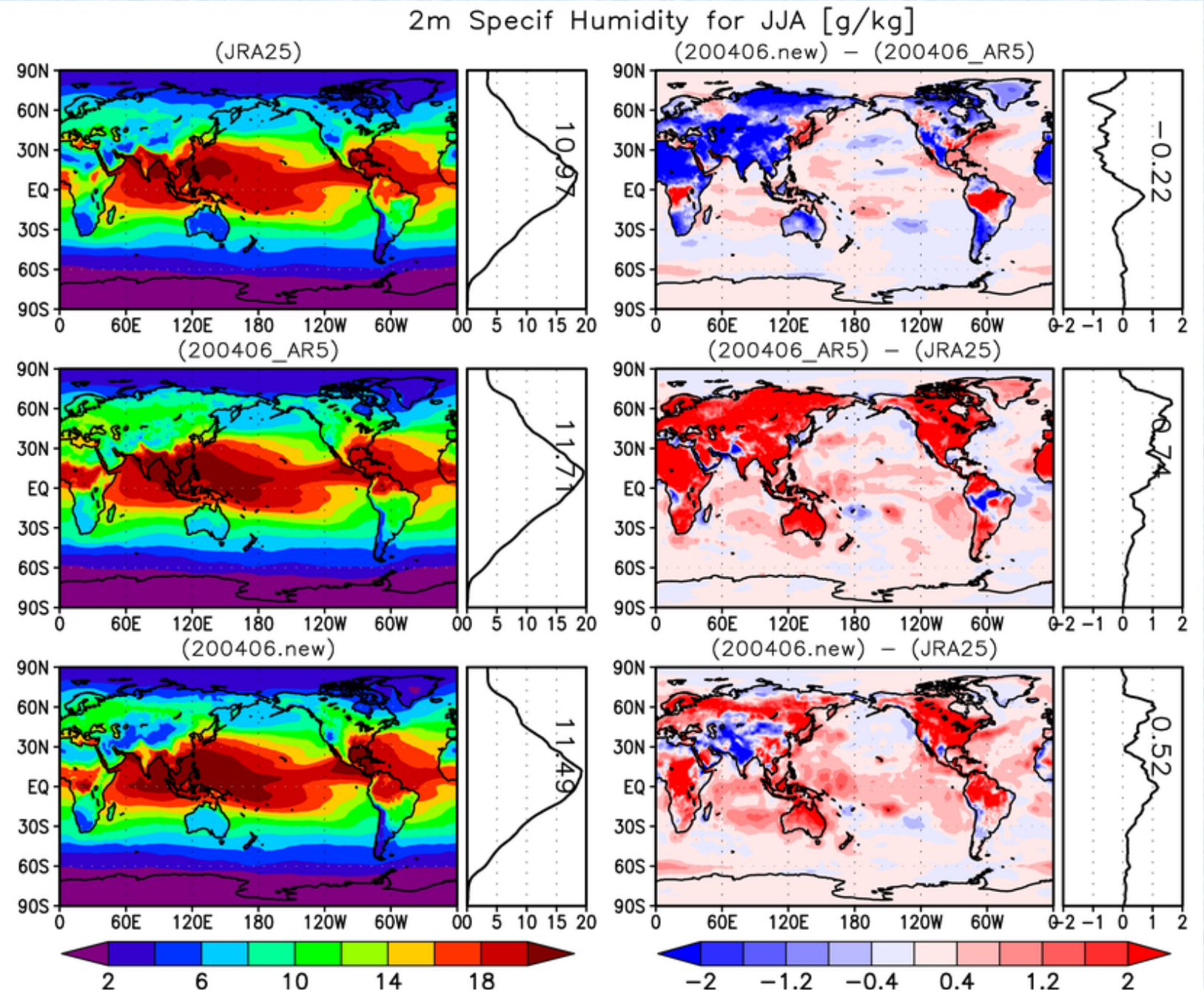
isccp_latlon_vis_JJA.png



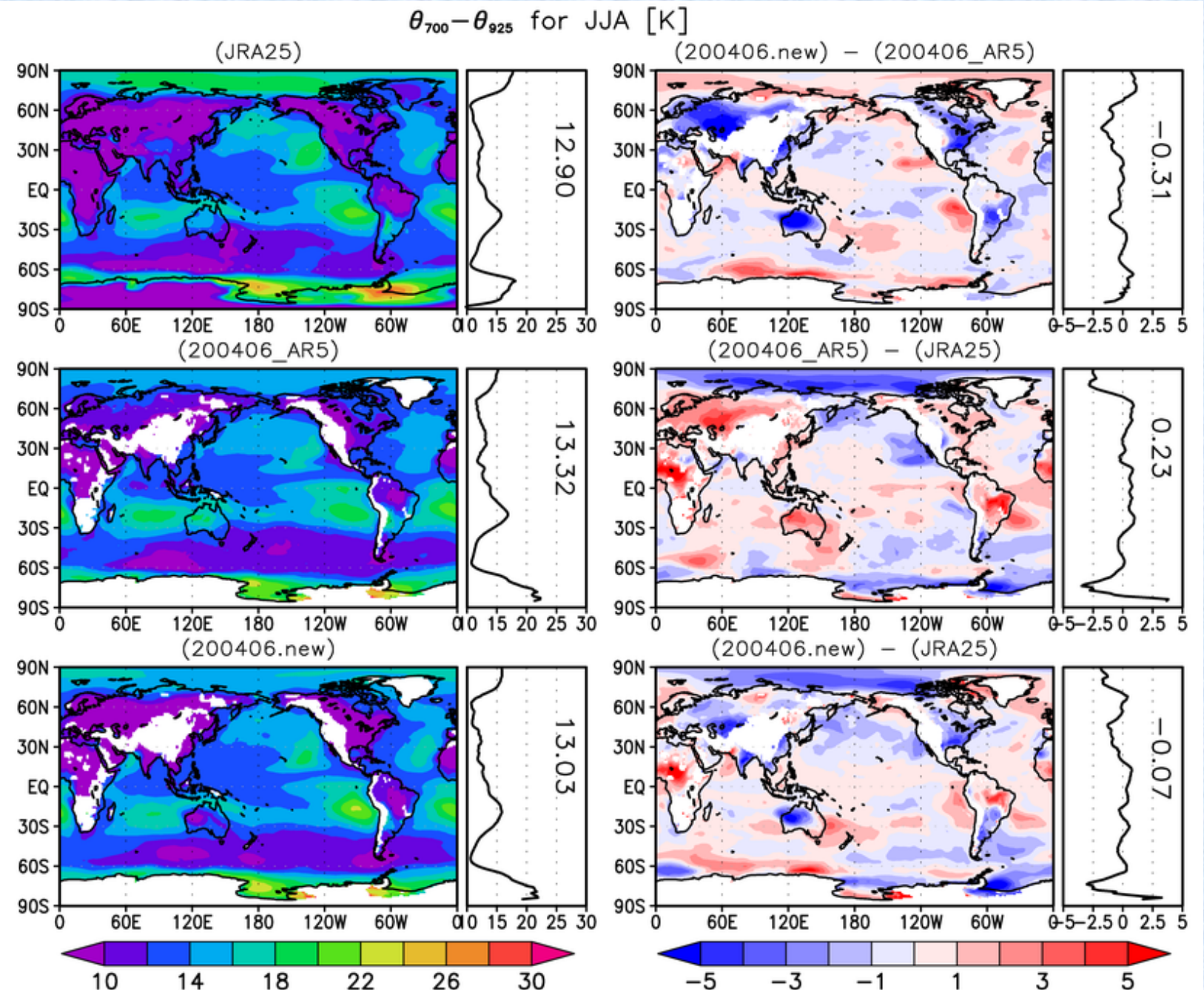
lat_lon_with_zm_t2m_JJA.png



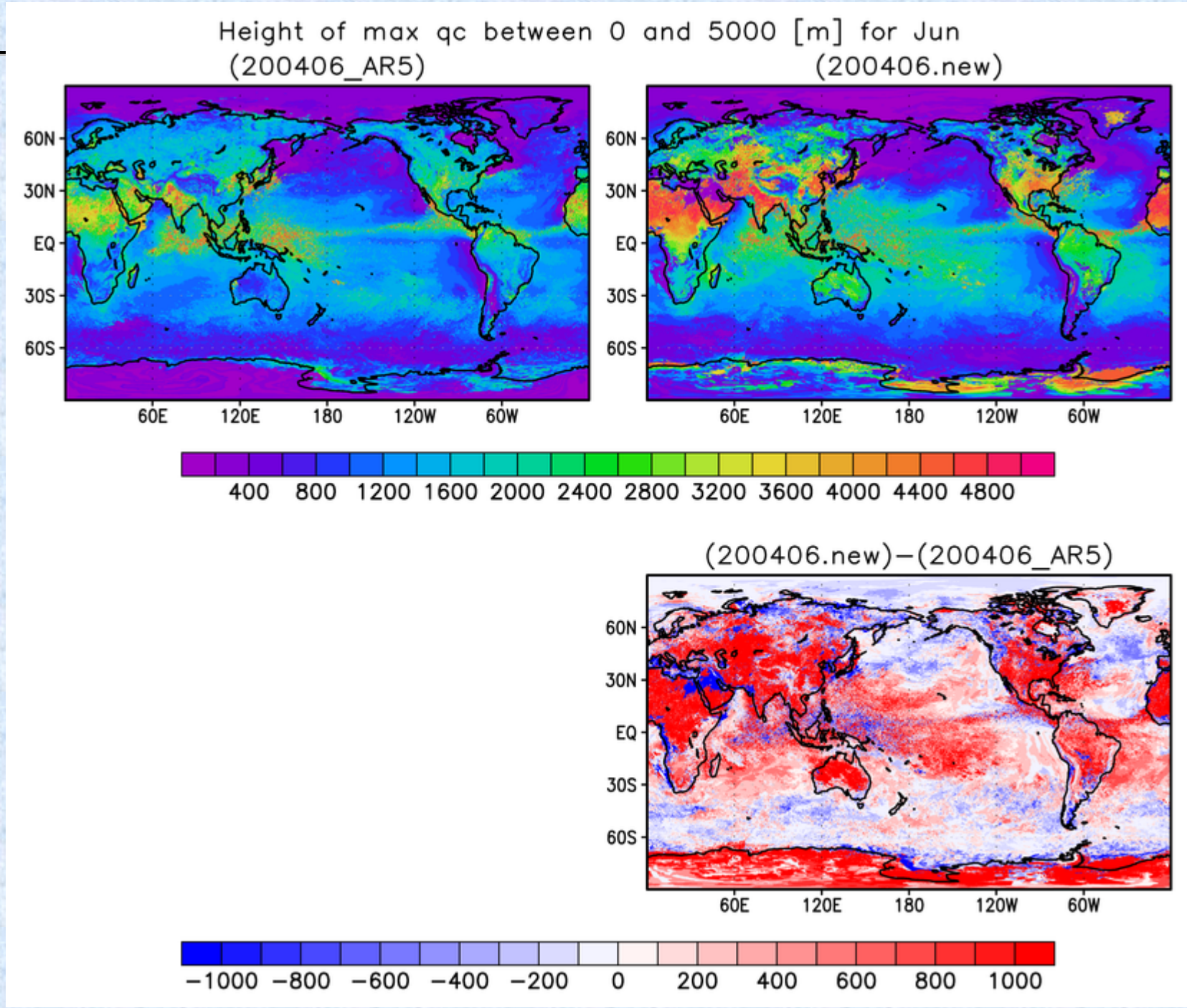
lat_lon_with_zm_qv2m_JJA.png



Low level stability

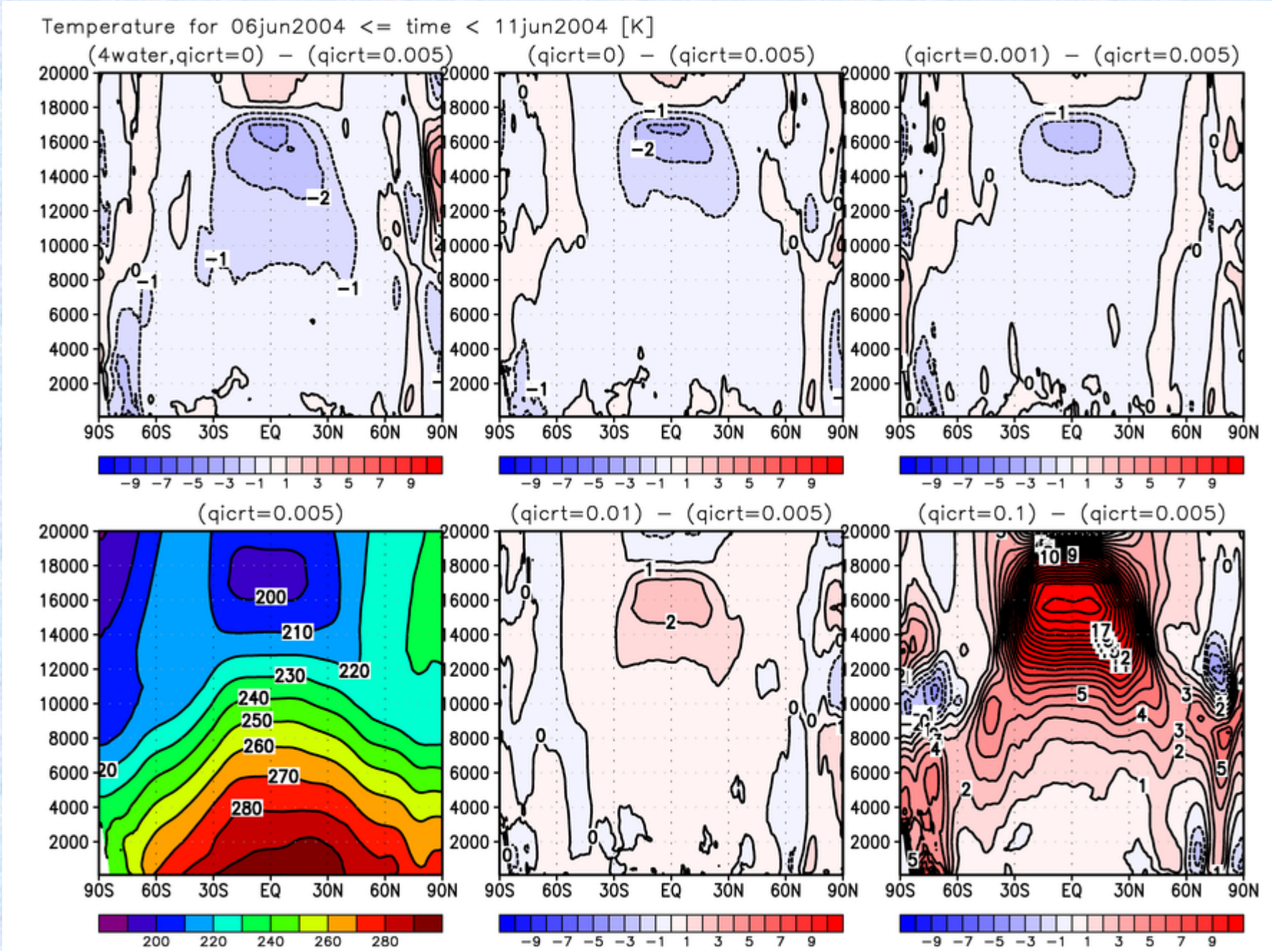


pbl_

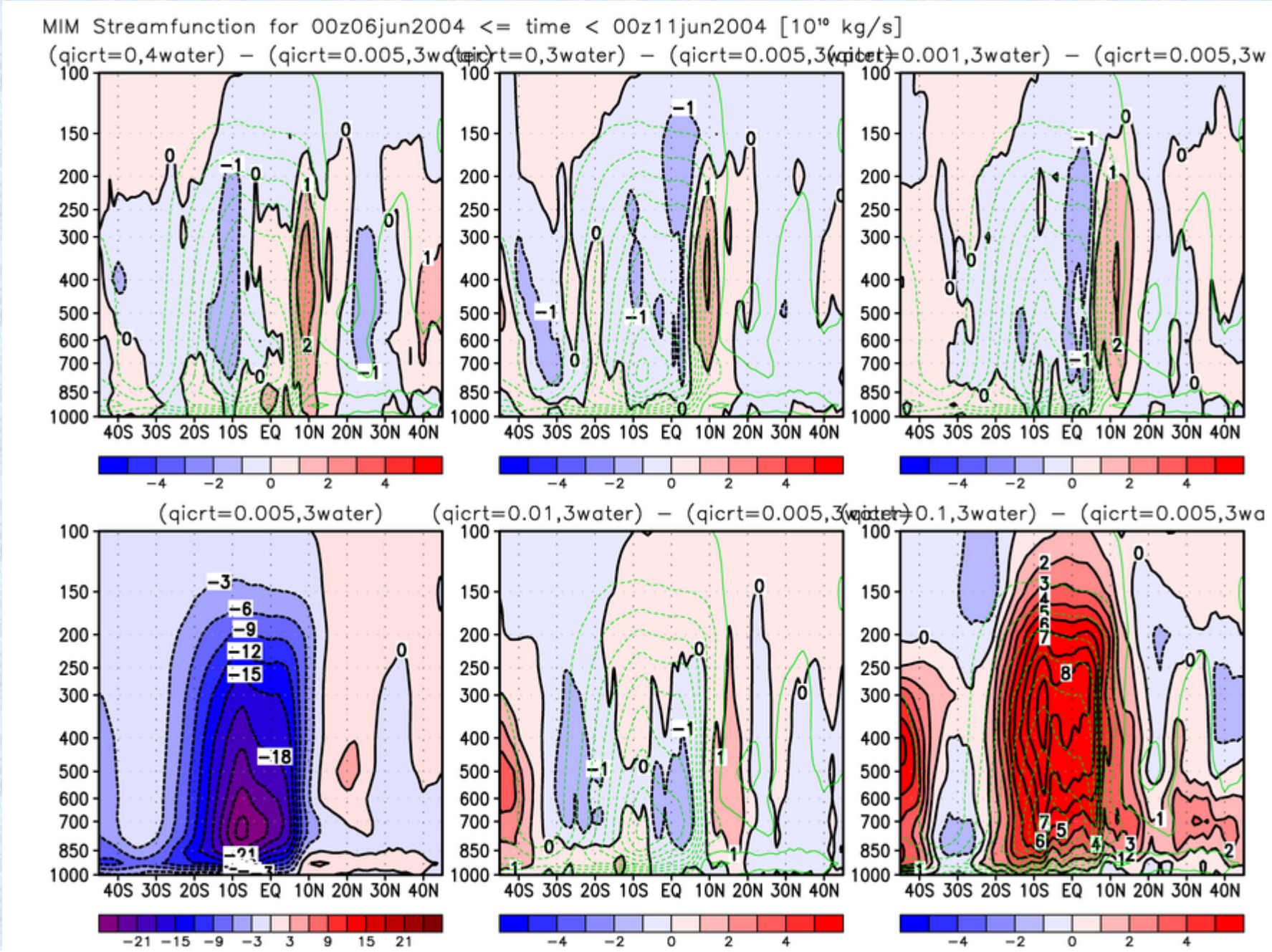

Height of max qc between 0 and 5000 [m] for Jun
(200406_AR5)
(200406.new)
60N
30N
EQ
30S
60S
60E
120E
180
120W
60W
400 800 1200 1600 2000 2400 2800 3200 3600 4000 4400 4800
(200406.new)−(200406_AR5)
−1000 −800 −600 −400 −200 0 200 400 600 800 1000

(Sensitivity Experiments)

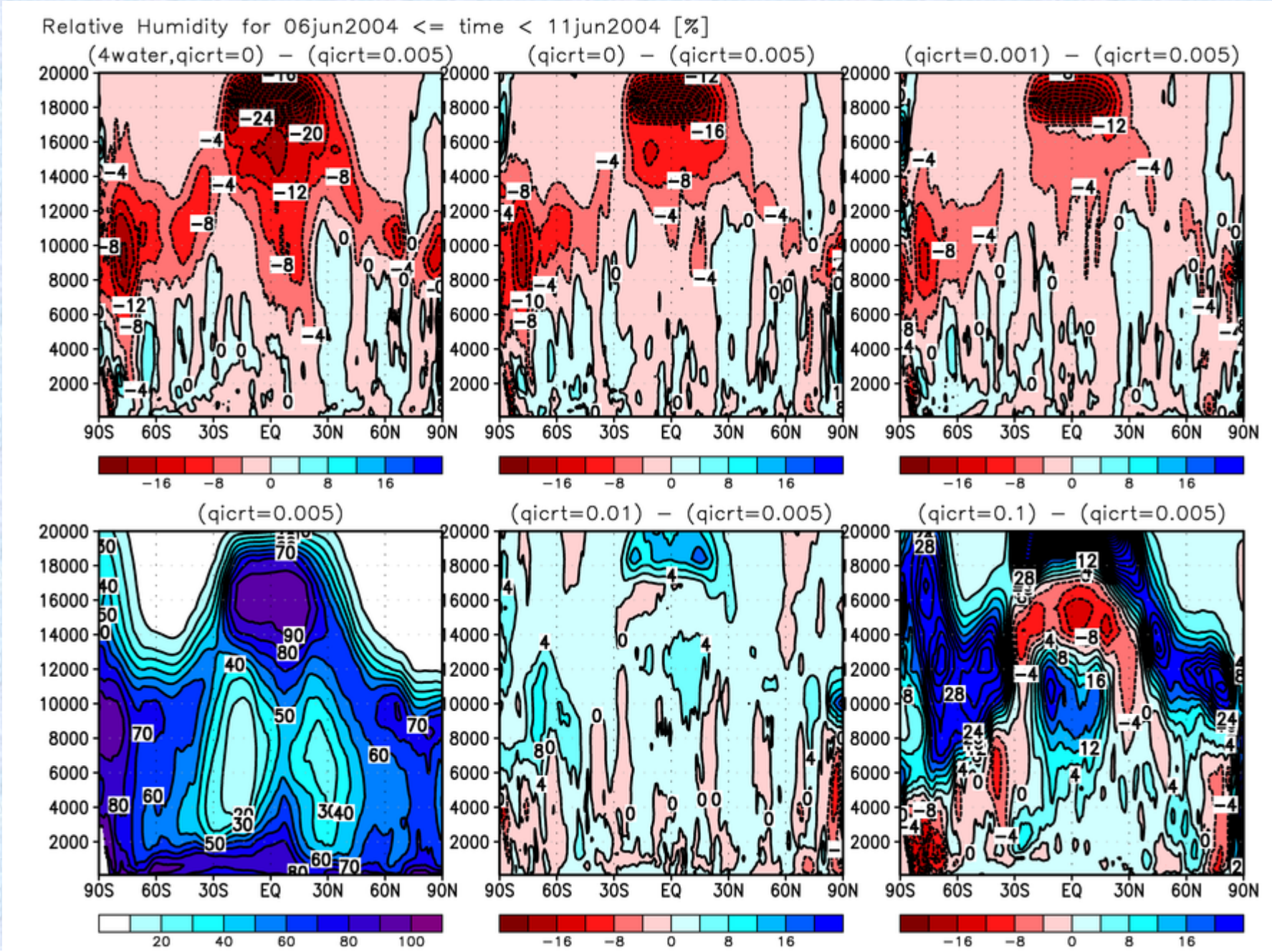
lat_lev_t_diff.png



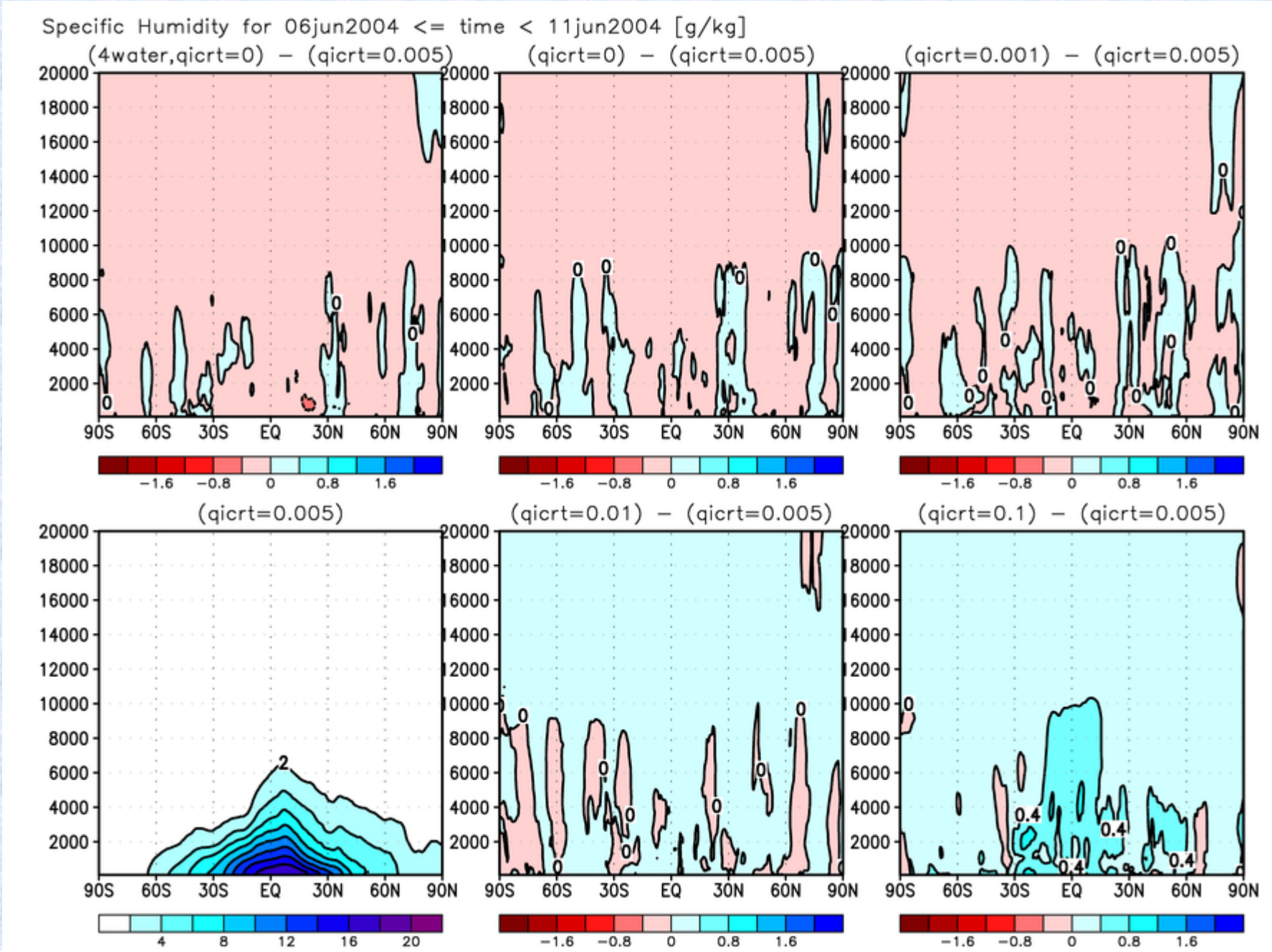
lat_lev_mim_st_diff.png



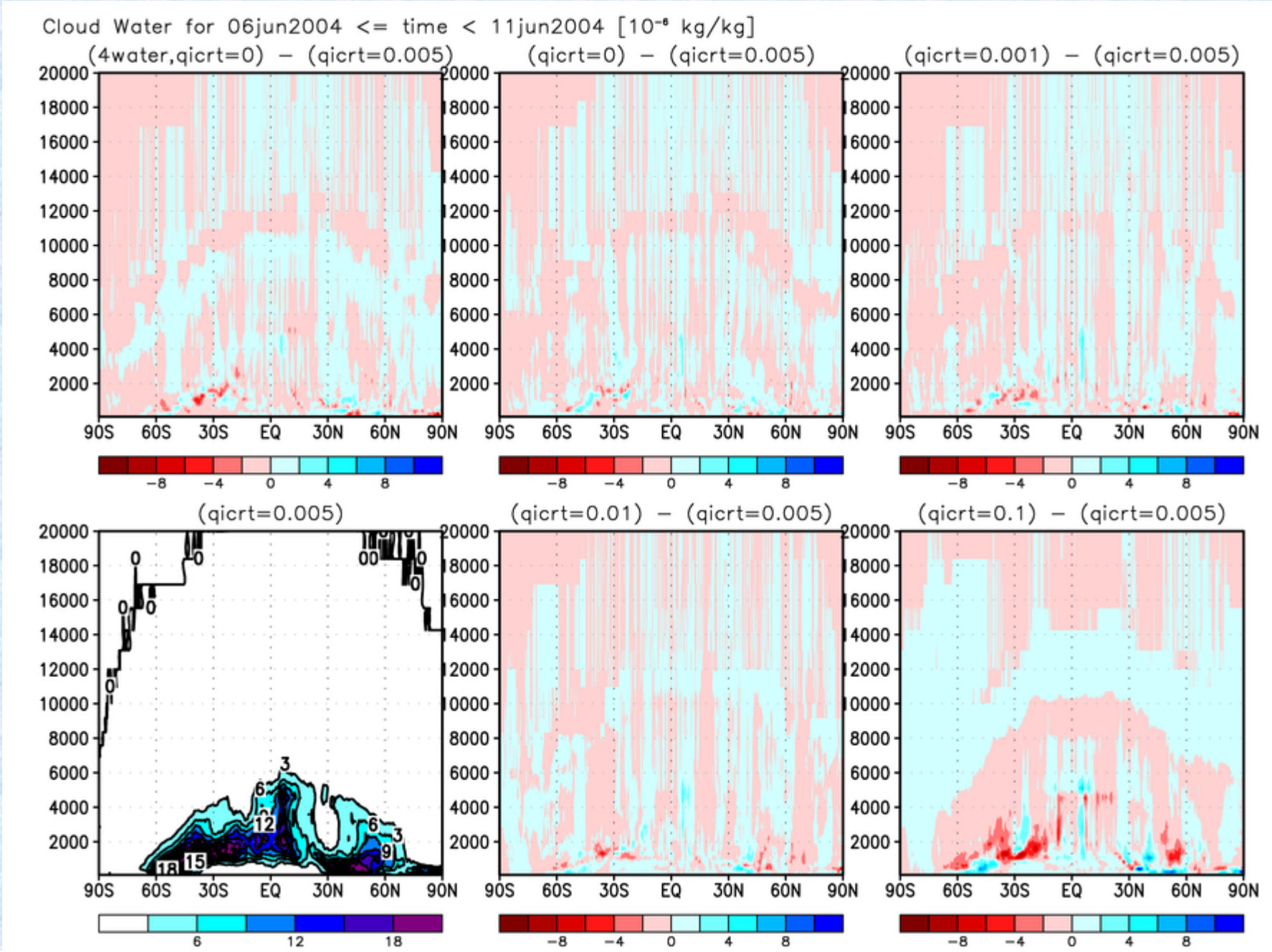
lat_lev_rh_diff.png



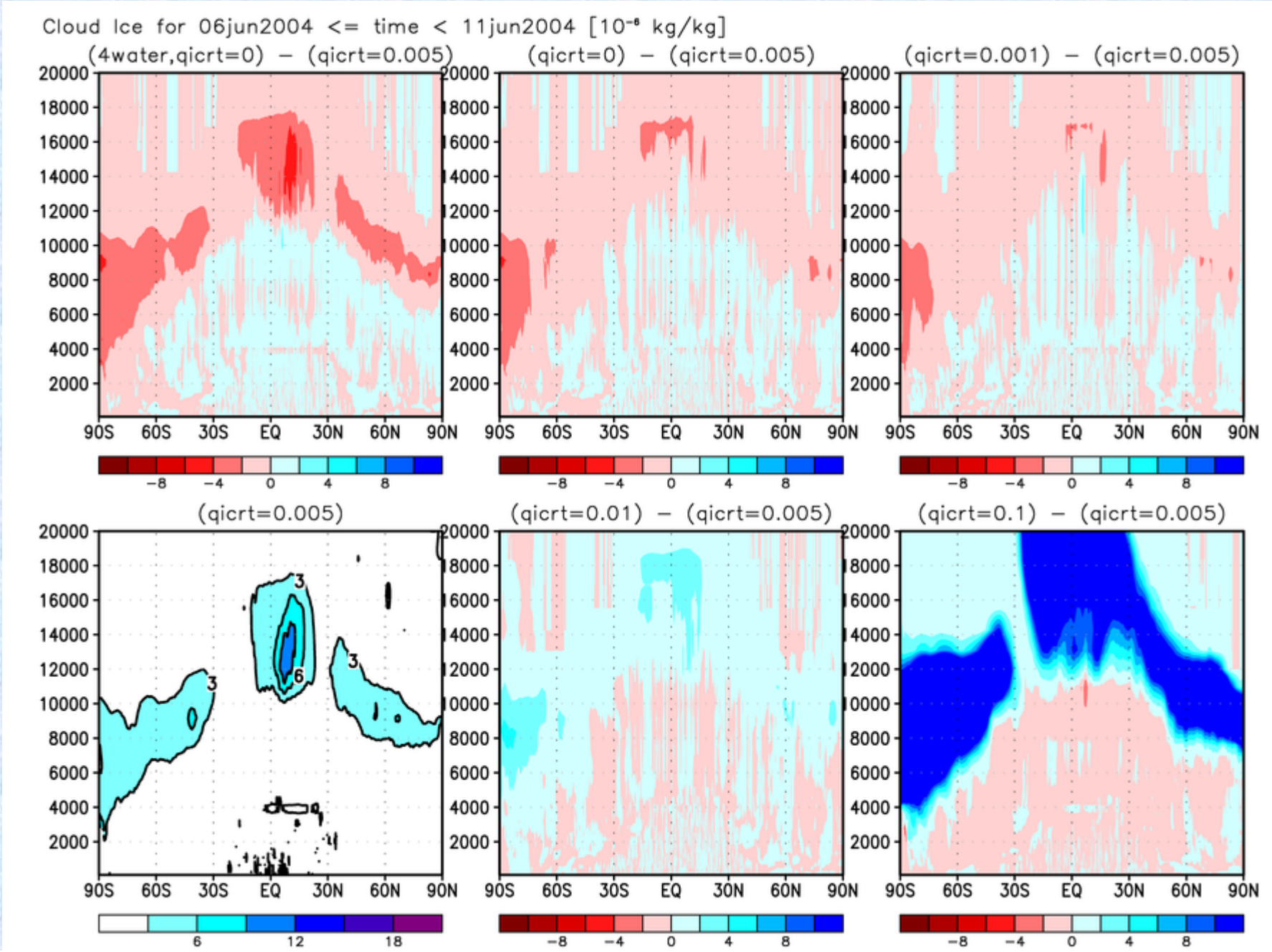
lat_lev_qv_diff.png



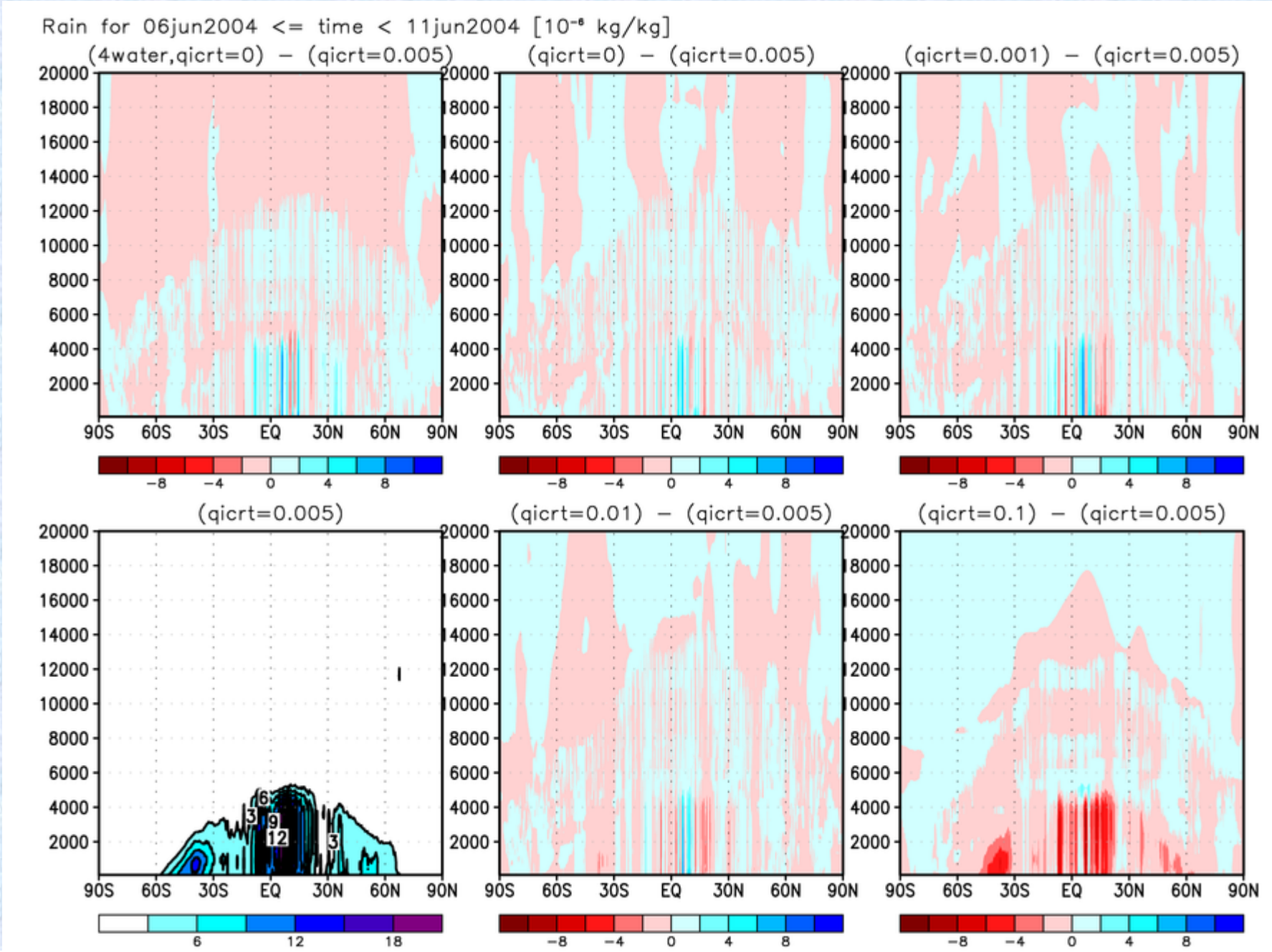
lat_lev_qc_diff.png



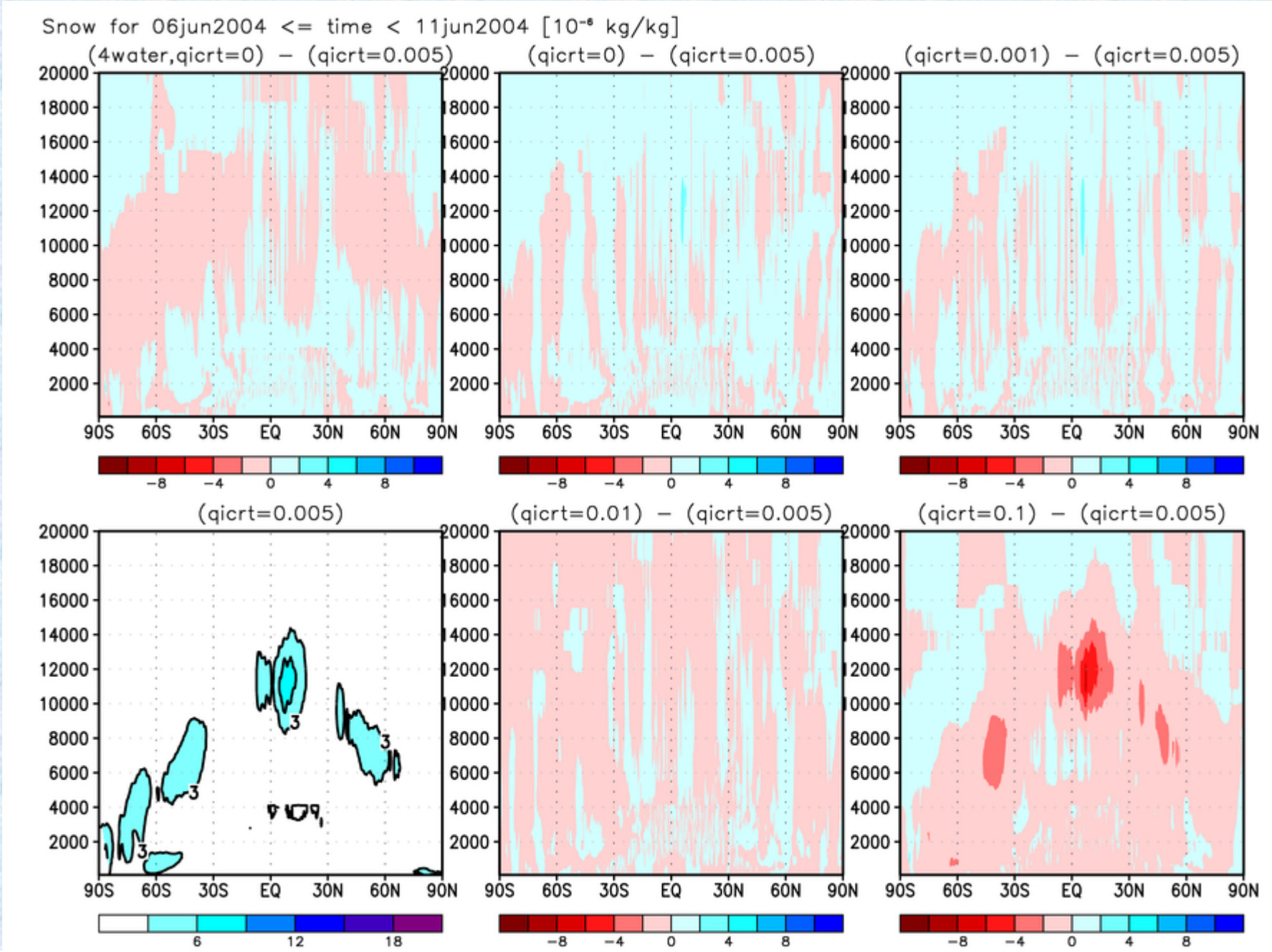
lat_lev_qi_diff.png



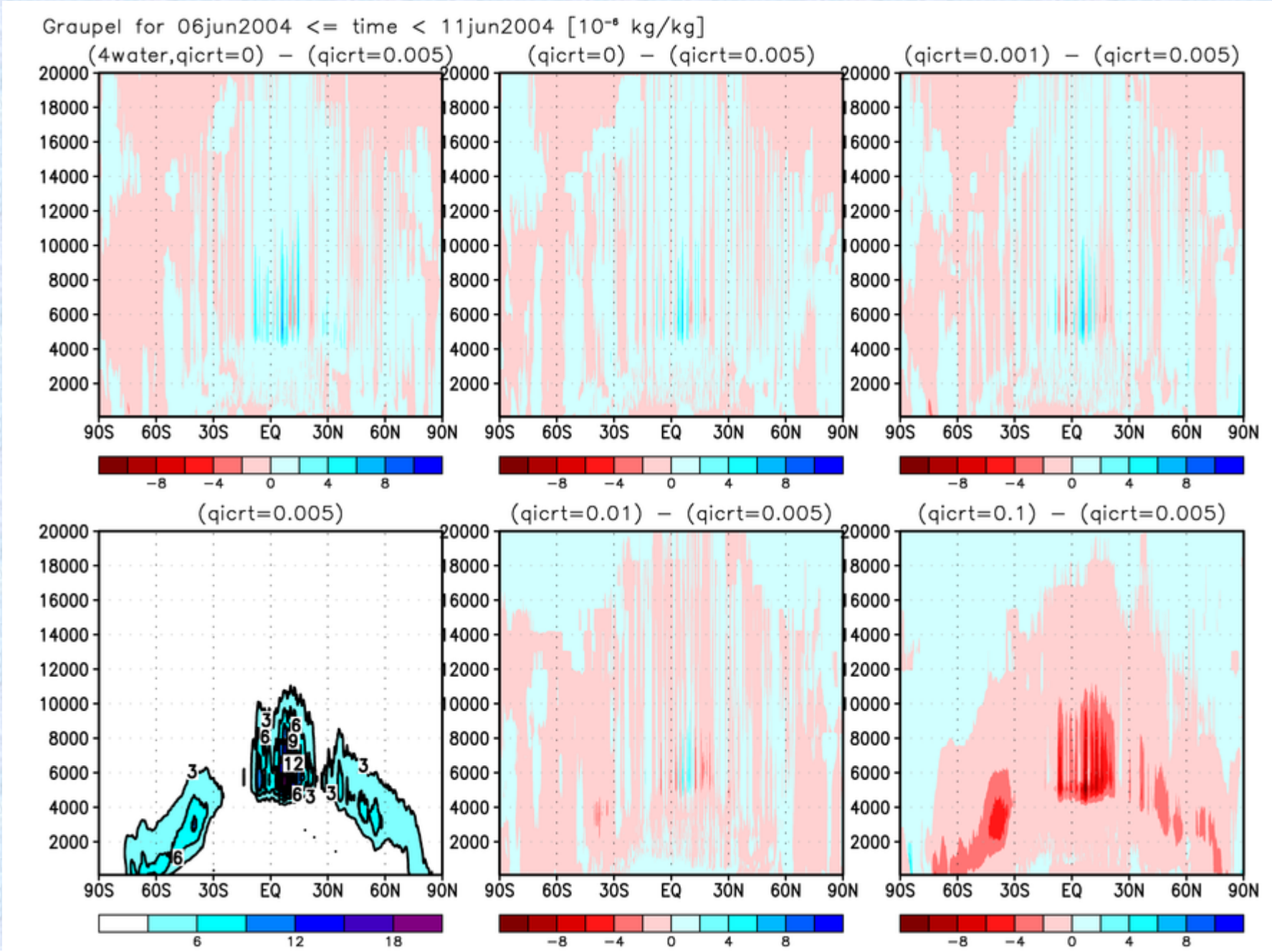
lat_lev_qr_diff.png



lat_lev_qs_diff.png



lat_lev_qg_diff.png



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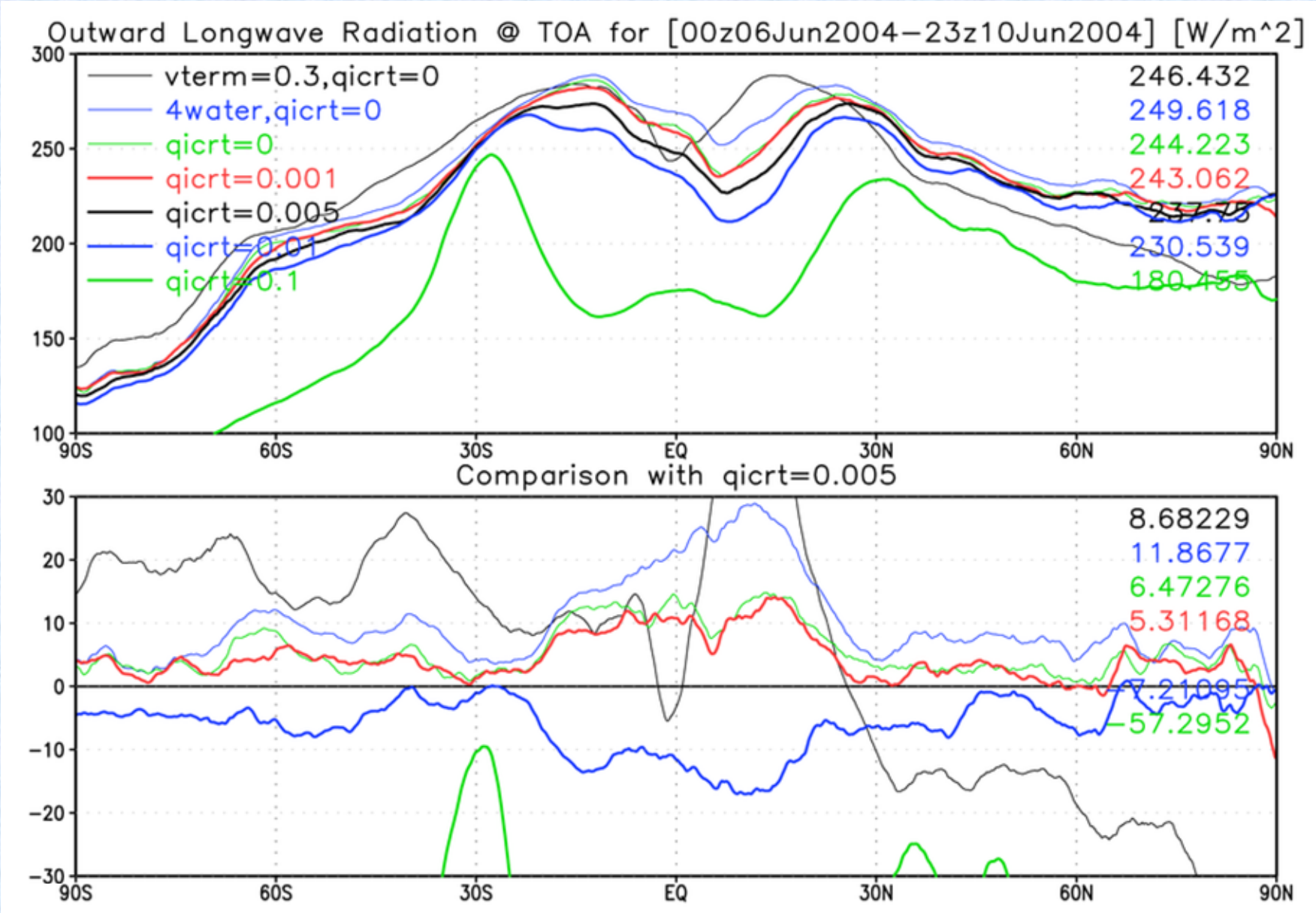

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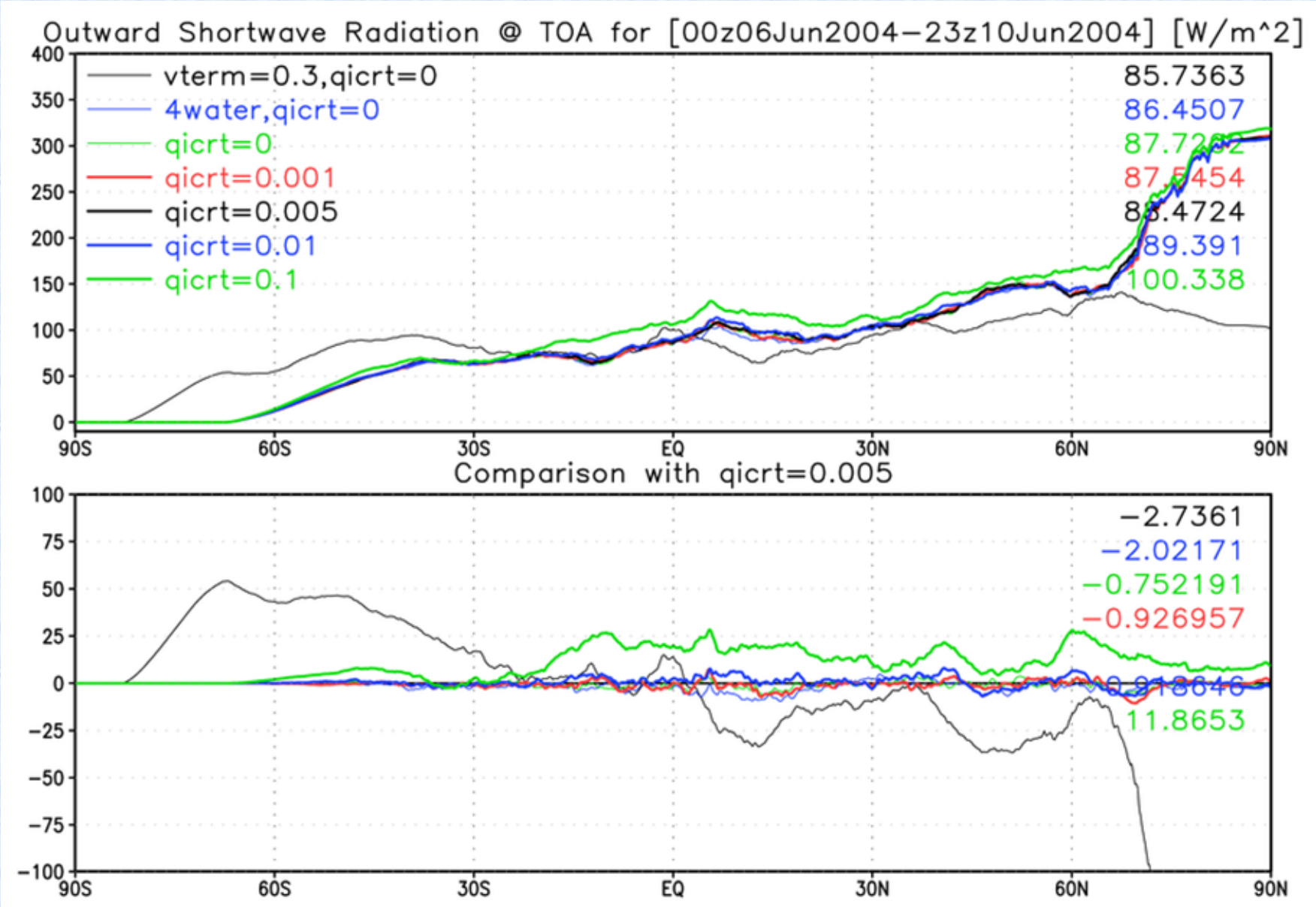
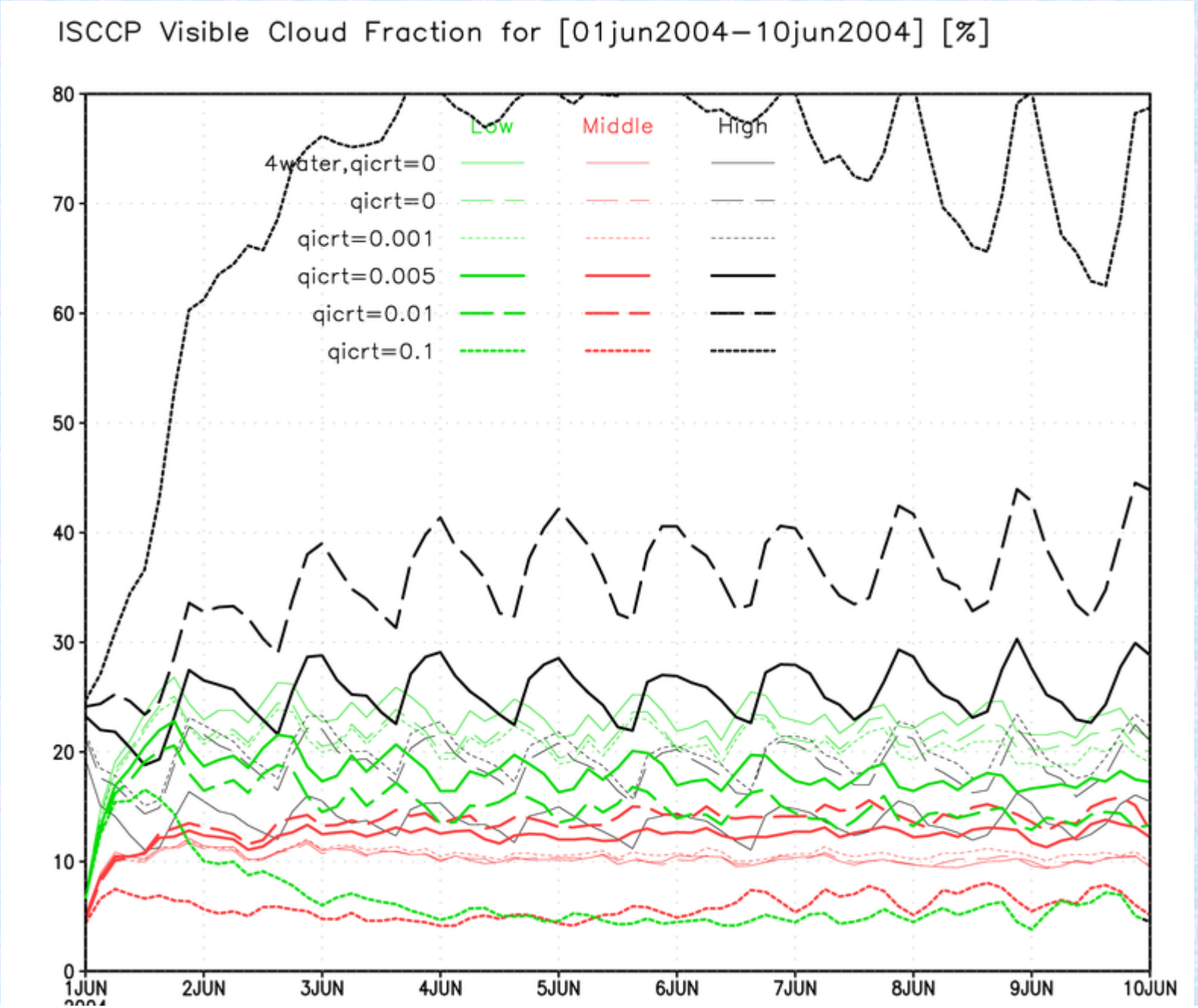


isccp_gm_evolution_vis.png



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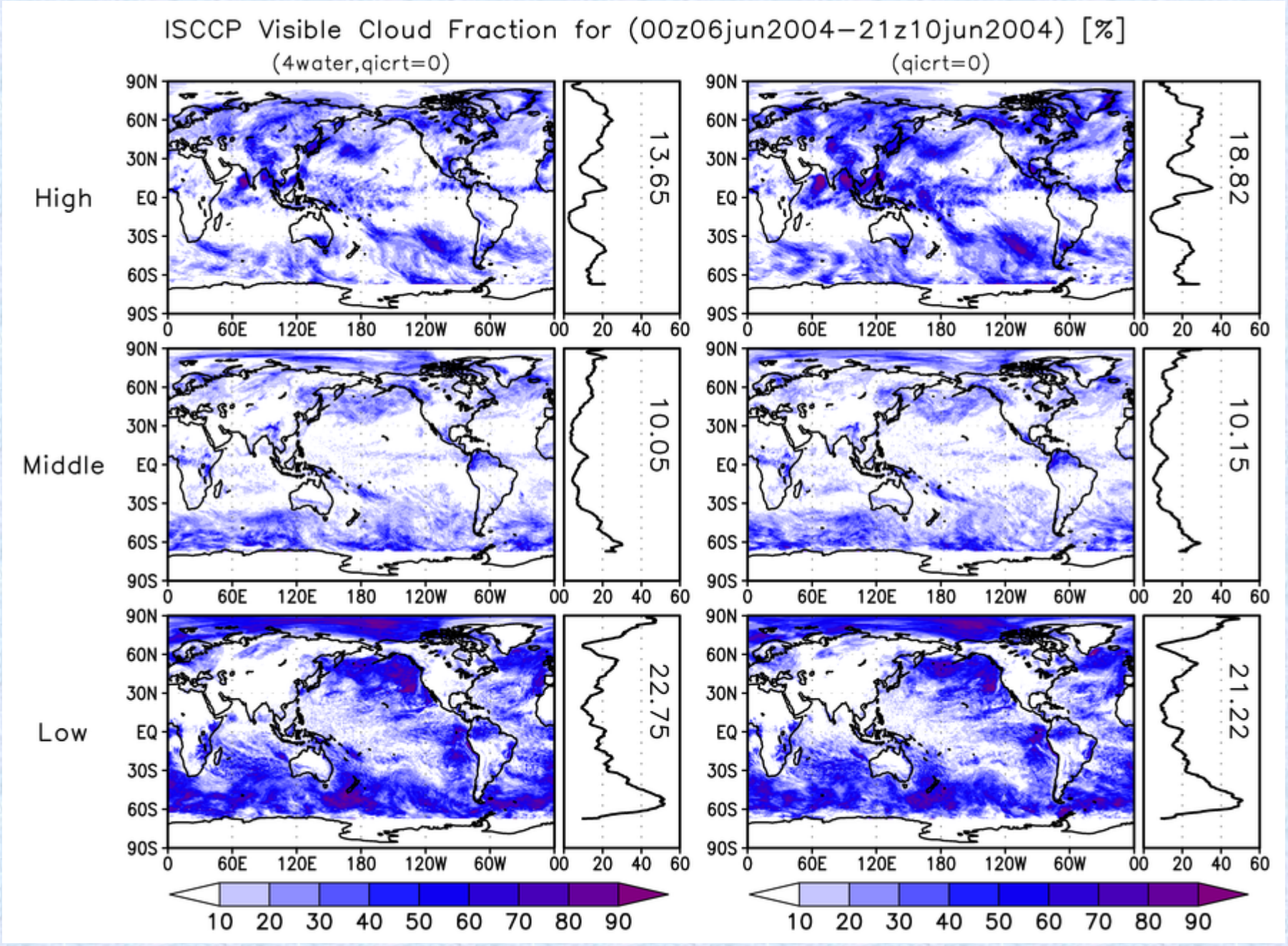

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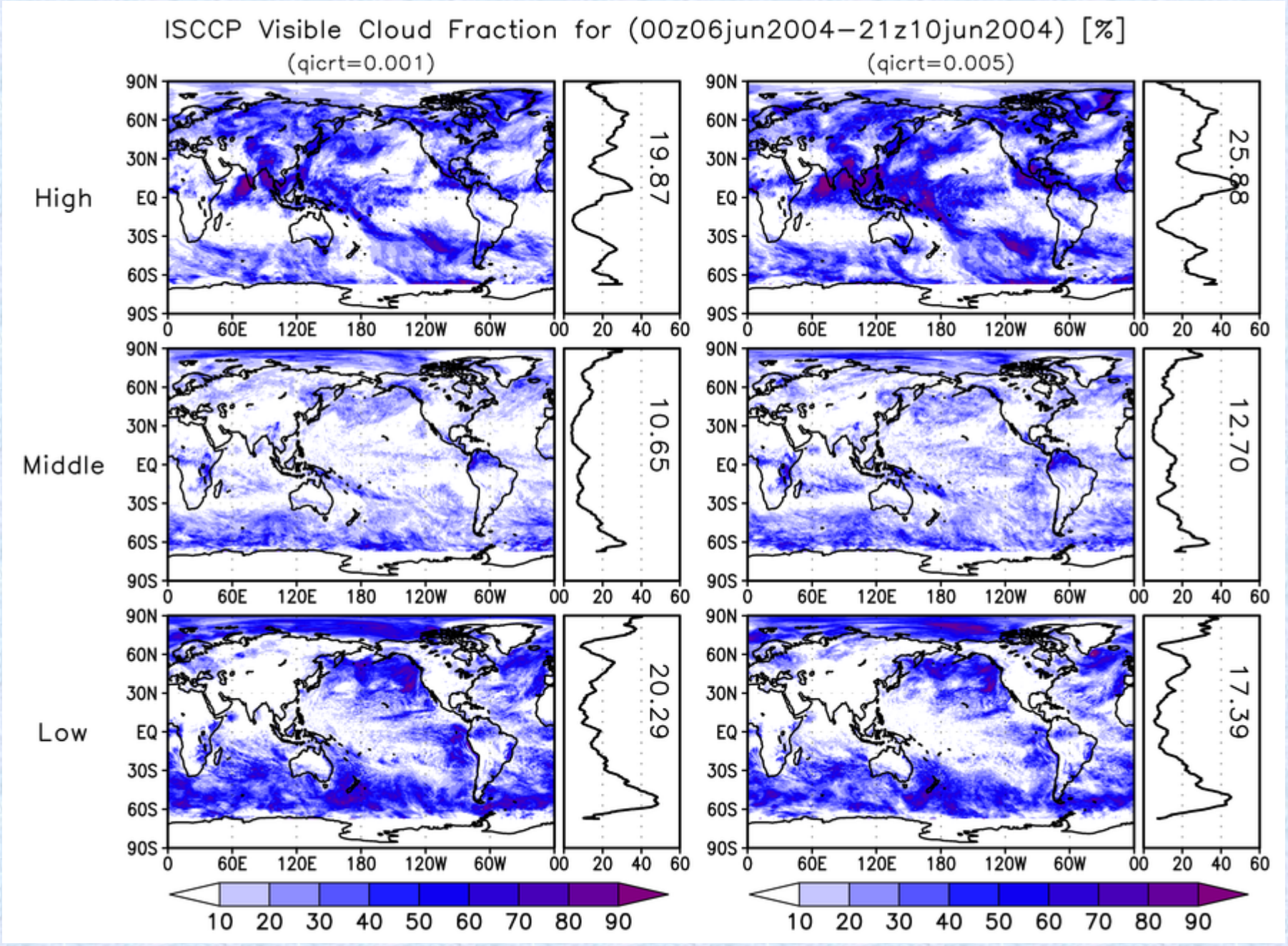
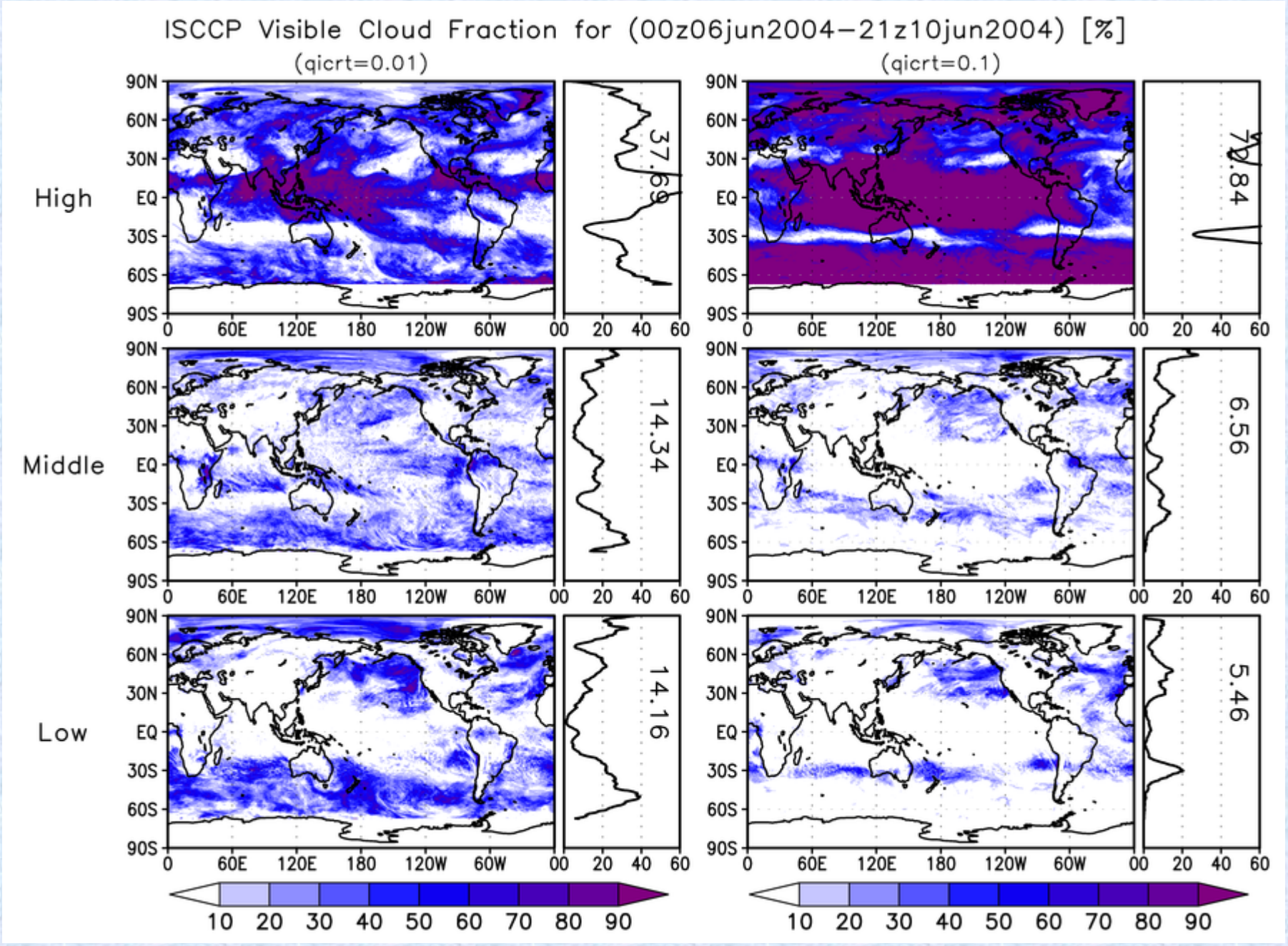
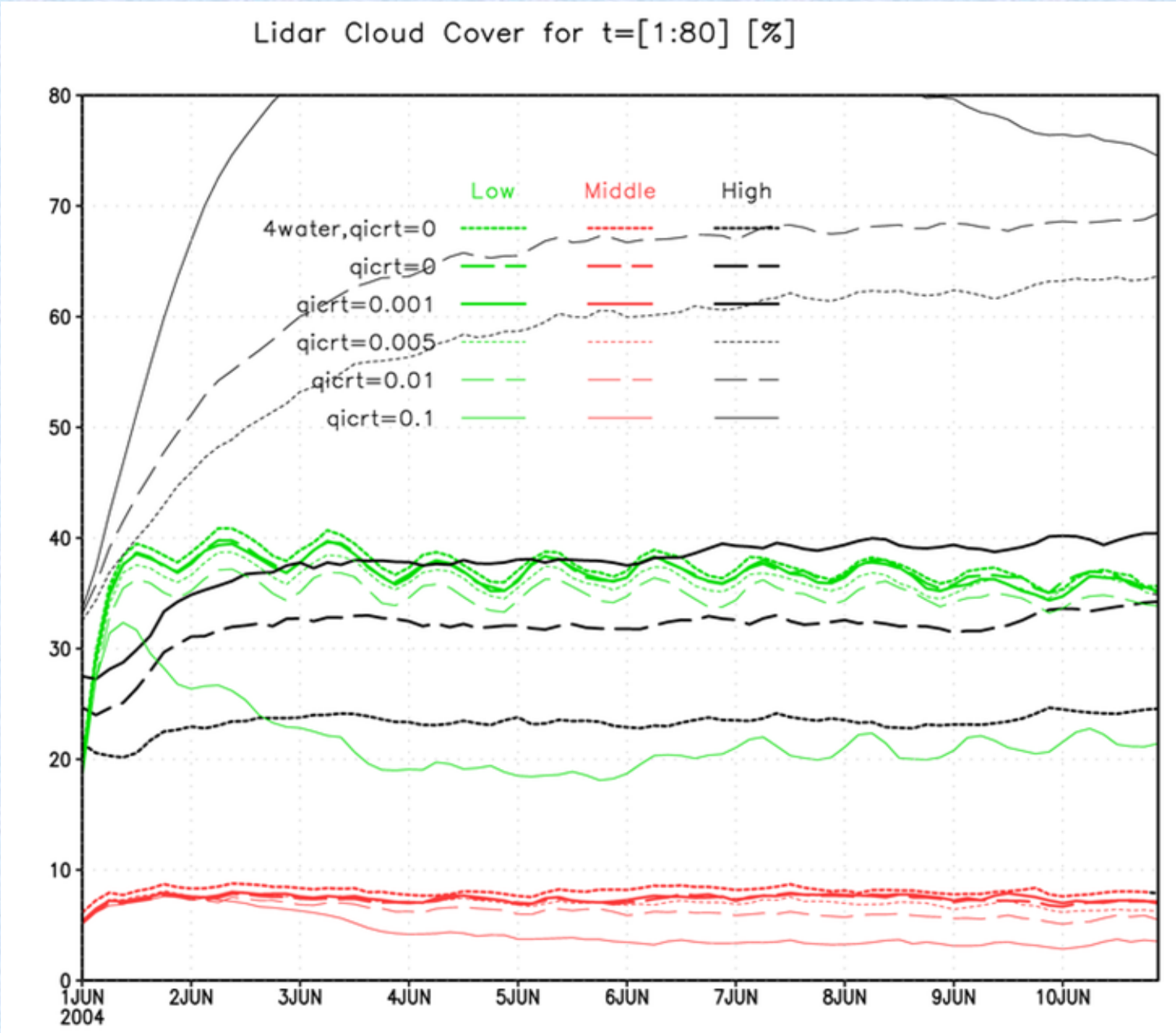


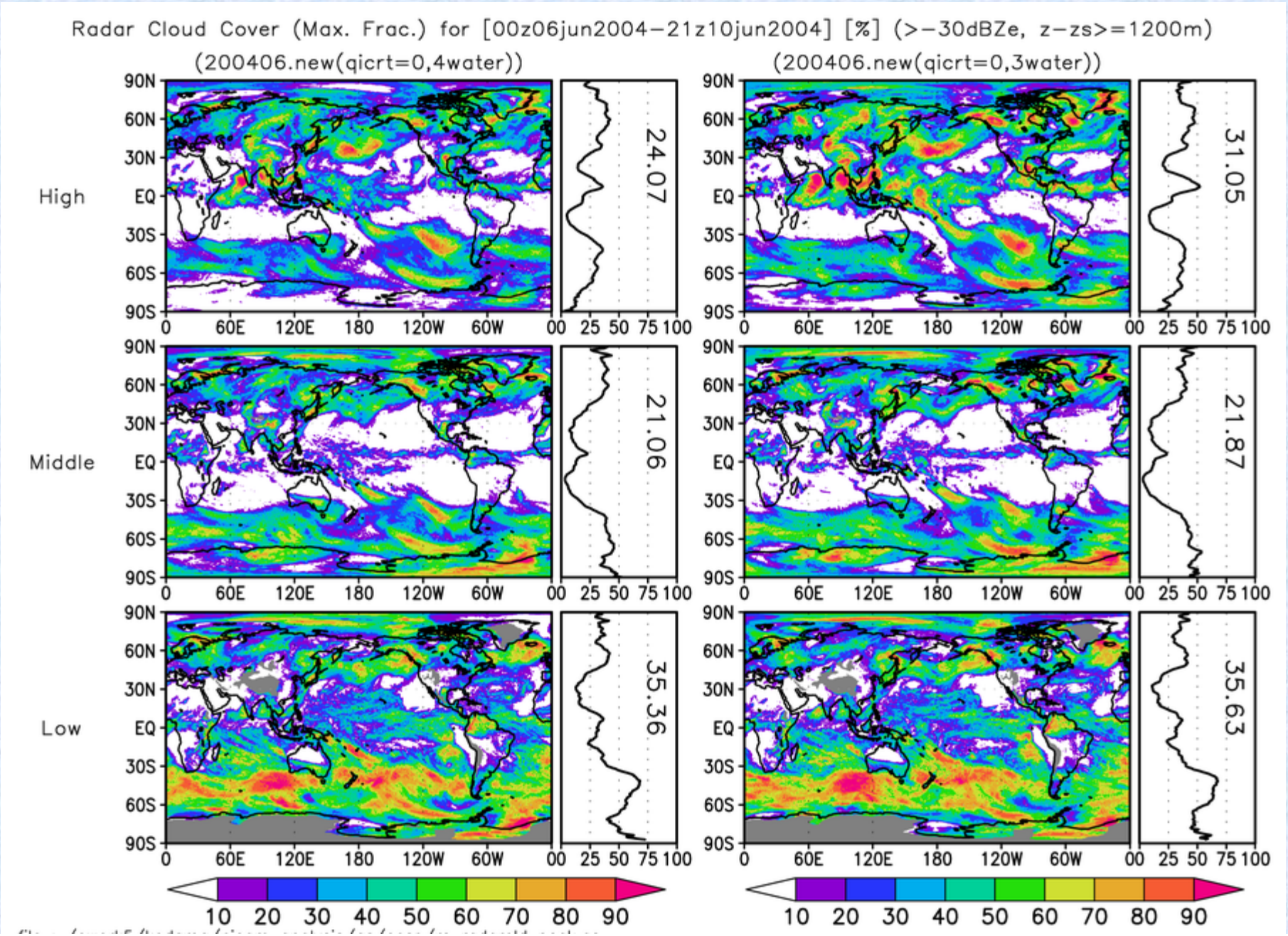
isccp_latlon_vis_3.png



ls_cldlayer_evolution.png



rs_radarcld_peak_1.png



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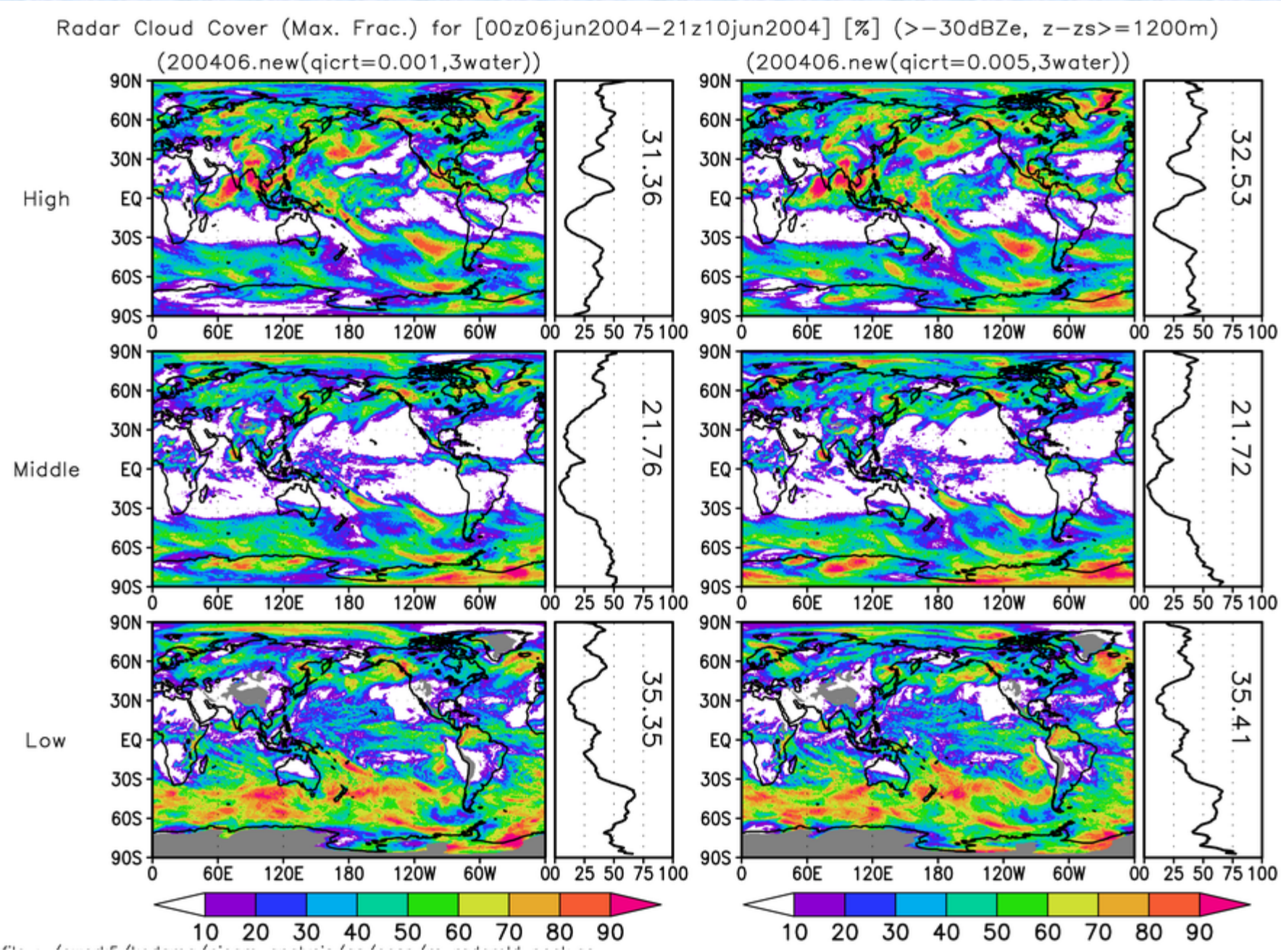

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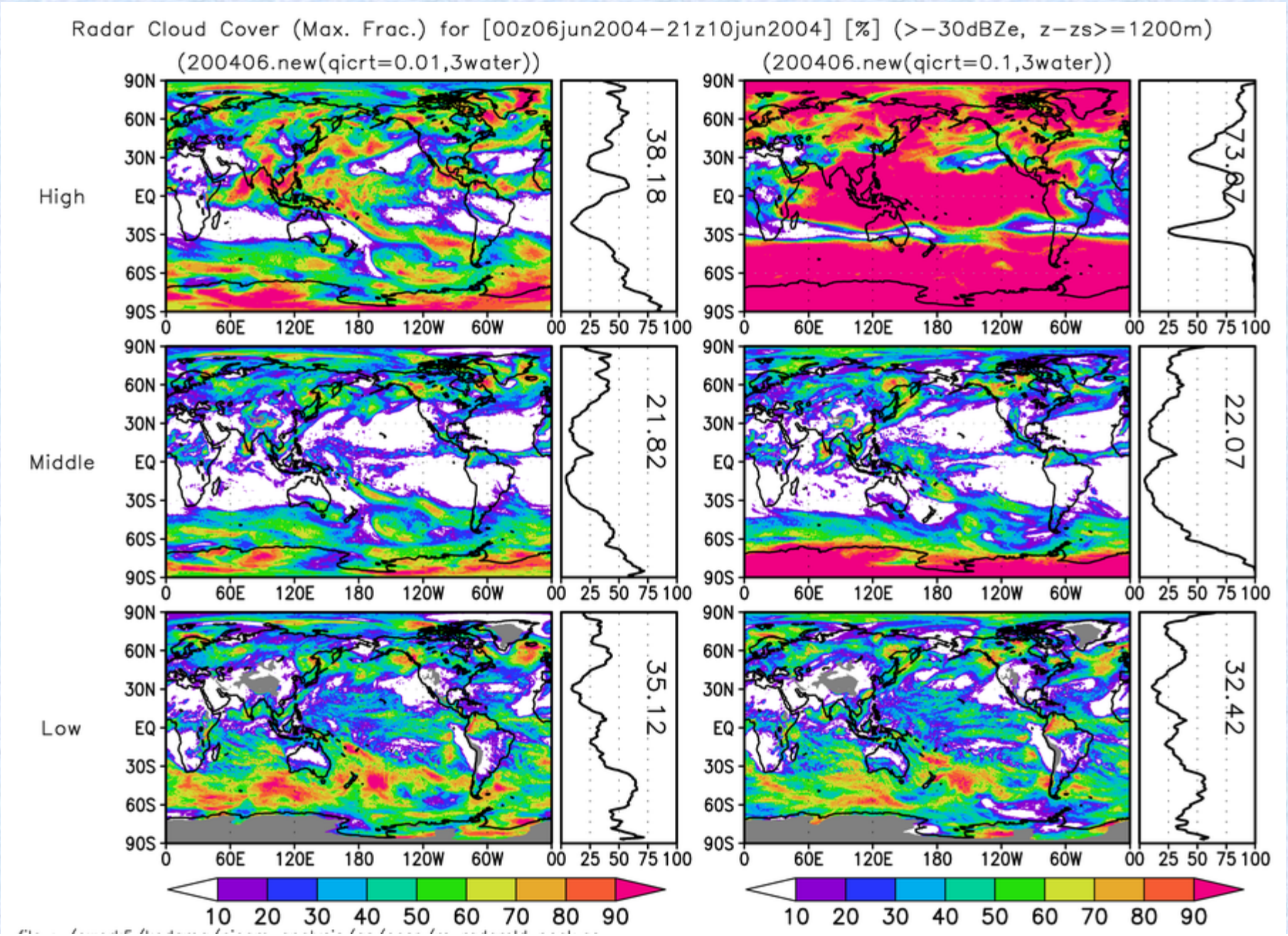
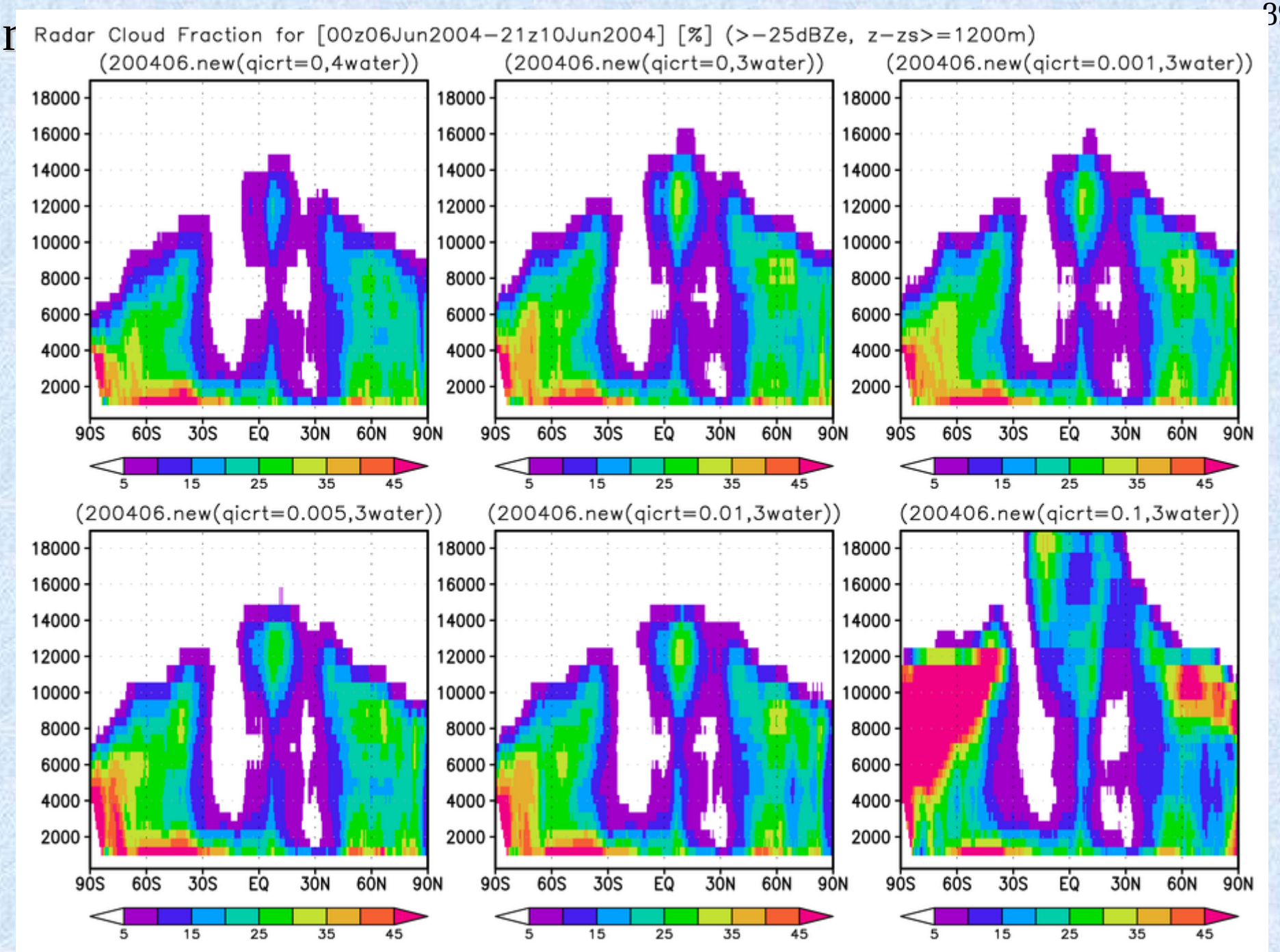
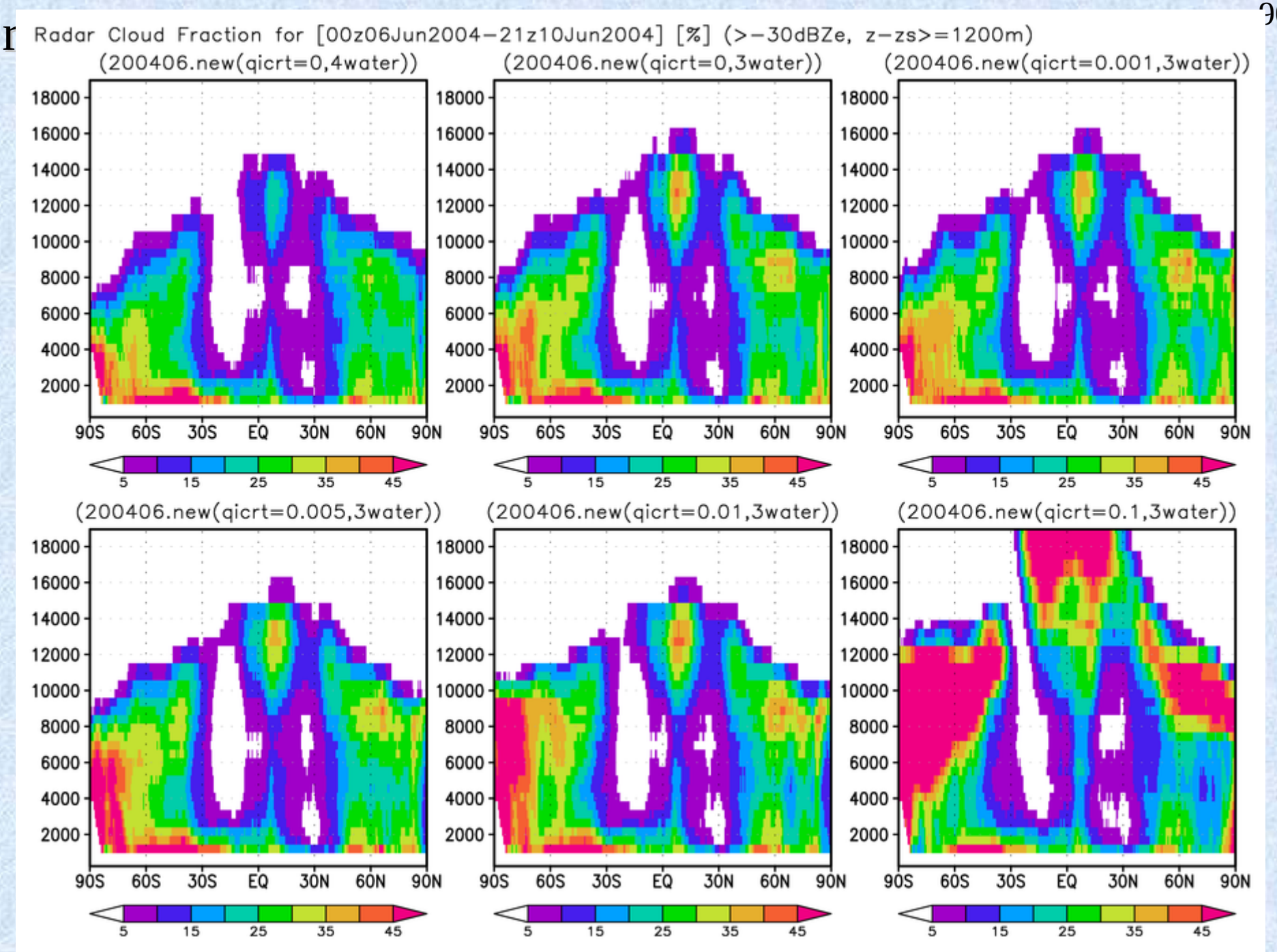



Radar Cloud Fraction for [00z06Jun2004-21z10Jun2004] [%] (>-25dBZe, z-zs>=1200m)
(200406.new(qicrt=0,4water))
(200406.new(qicrt=0,3water))
(200406.new(qicrt=0.001,3water))
(200406.new(qicrt=0.005,3water))
(200406.new(qicrt=0.01,3water))
(200406.new(qicrt=0.1,3water))
18000
16000
14000
12000
10000
8000
6000
4000
2000
90S 60S 30S EQ 30N 60N 90N
5 15 25 35 45


Radar Cloud Fraction for [00z06Jun2004-21z10Jun2004] [%] (>-30dBZe, z-zs>=1200m)
(200406.new(qicrt=0,4water))
(200406.new(qicrt=0,3water))
(200406.new(qicrt=0.001,3water))
(200406.new(qicrt=0.005,3water))
(200406.new(qicrt=0.01,3water))
(200406.new(qicrt=0.1,3water))
18000
16000
14000
12000
10000
8000
6000
4000
2000
90S 60S 30S EQ 30N 60N 90N
5 15 25 35 45

(Other)

Summary of the sens. exp.

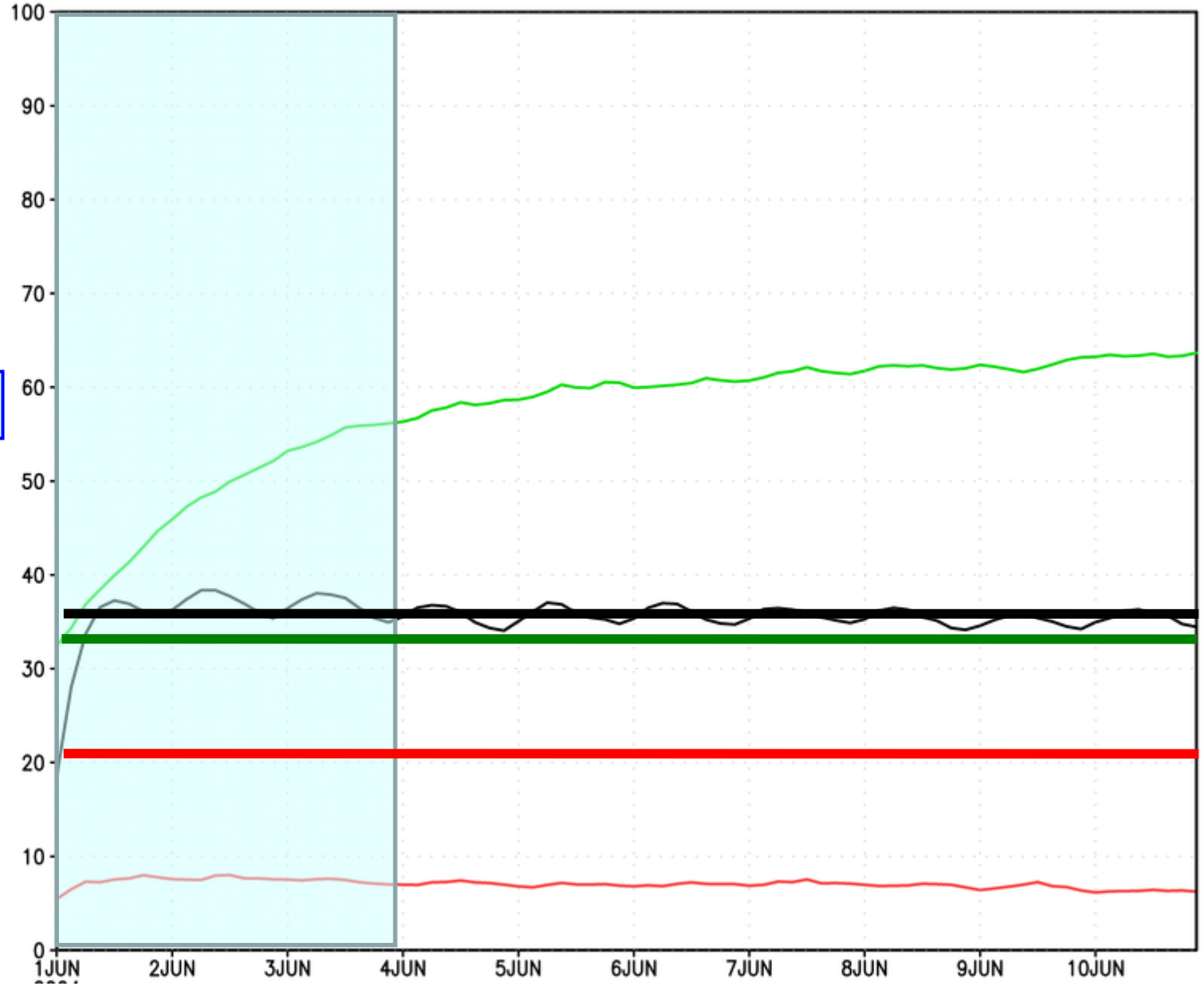
Table 2. Global mean cloud fractions for each sensitivity experiment [%].

	ISCCP			CALIPSO			CloudSat		
	High	Middle	Low	High	Middle	Low	High	Middle	Low
qicrt0.1-3water	72.84	6.56	5.46	81.15	3.22	16.09	73.67	22.07	32.42
qicrt0.01-3water	37.69	14.34	14.16	67.97	5.89	34.18	38.18	21.82	35.12
qicrt0.05-3water	25.88	12.70	17.39	61.94	6.89	35.36	32.53	21.72	35.41
qicrt0.001-3water	19.87	10.65	20.29	39.25	7.53	35.95	31.36	21.76	35.35
qicrt0-3water	18.82	10.15	21.22	32.60	7.42	36.16	31.05	21.87	35.63
qicrt0-4water	13.65	10.05	22.75	23.58	8.18	36.55	24.07	21.06	35.36

Global Mean CALIPSO Cloud Fraction [%]

緑：上層雲
赤：中層雲
黒：下層雲

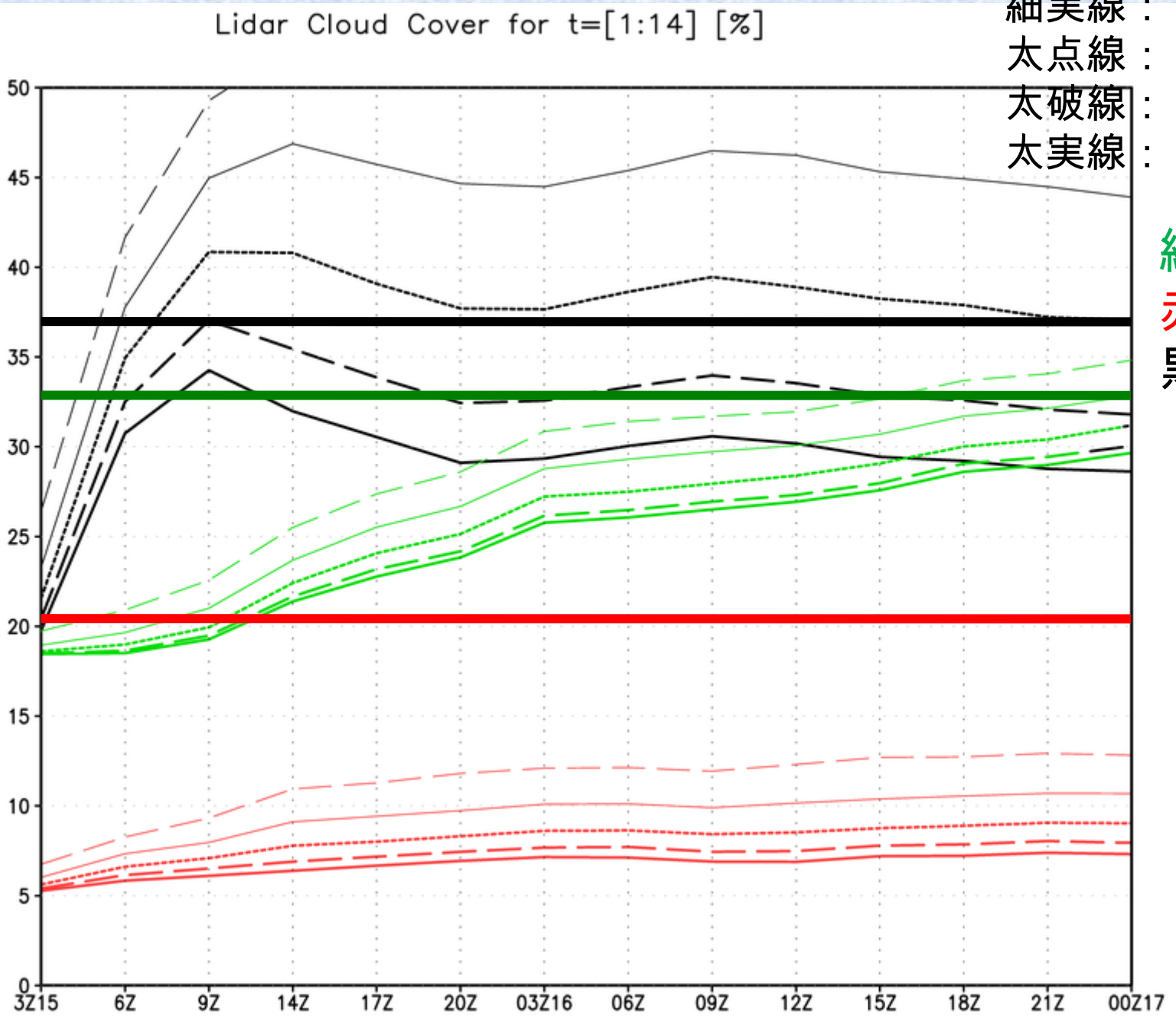
新物理 GL09



Global Mean CALIPSO Cloud Fraction [%] (YOPC)

細破線： 640×320
細実線： 1280×640
太点線： 2560×1280
太破線： 5120×2560
太実線： 10240×5120

緑：上層雲
赤：中層雲
黒：下層雲



ls_cldlayer_JJA.png