

Climatology of cloud and precipitation over CONTRAST region

Chuntao Liu

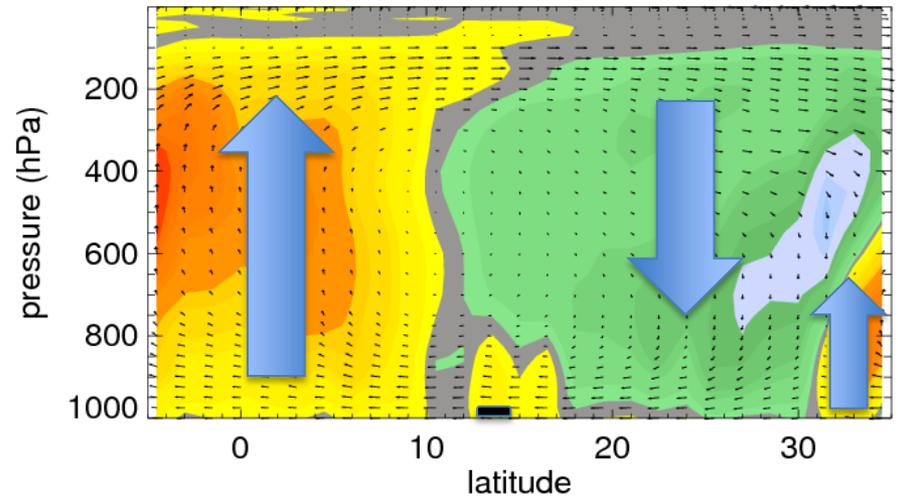
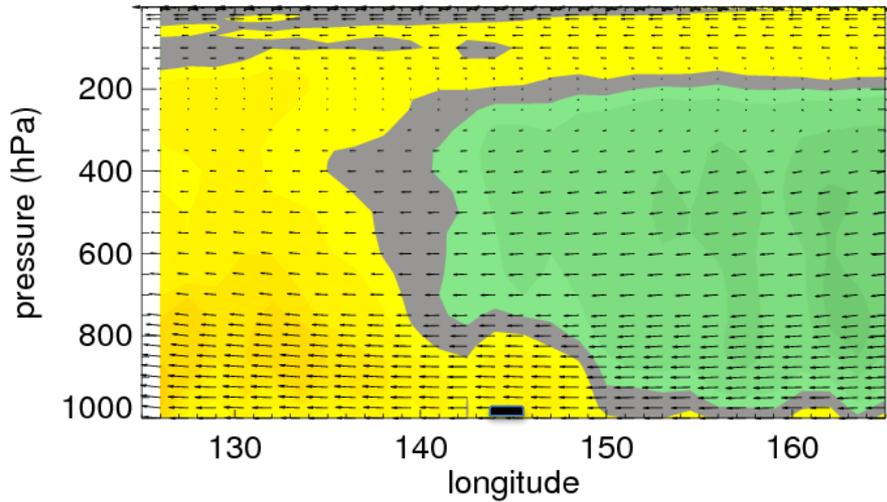
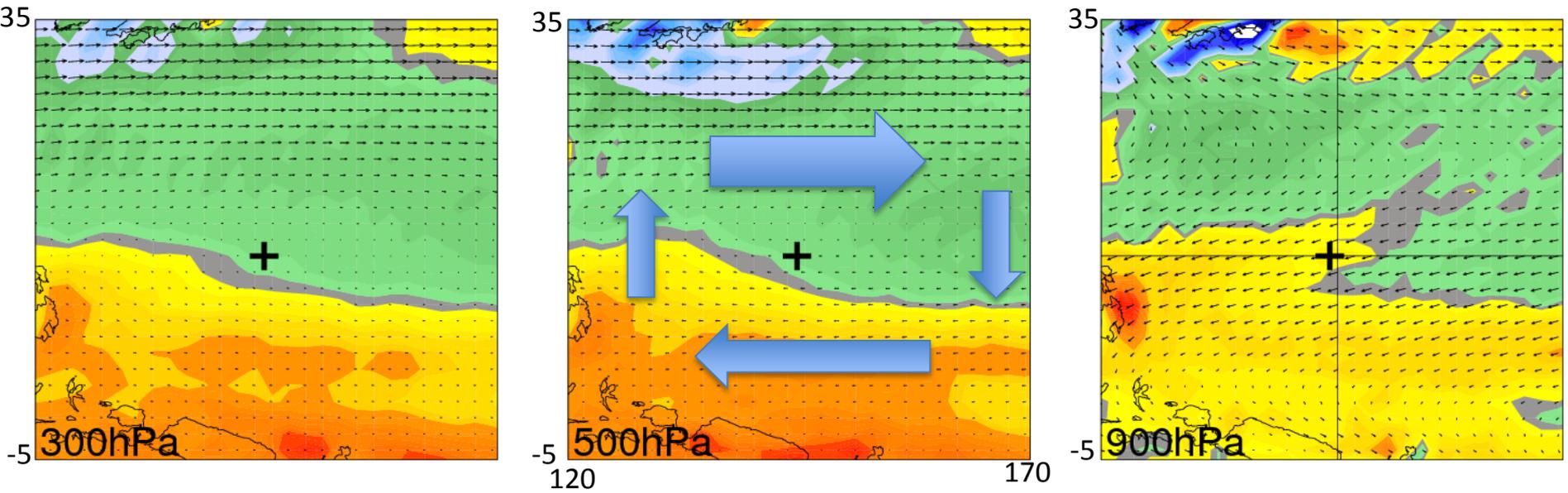
Texas A&M University - Corpus Christi

Laura Pan

NCAR ACD

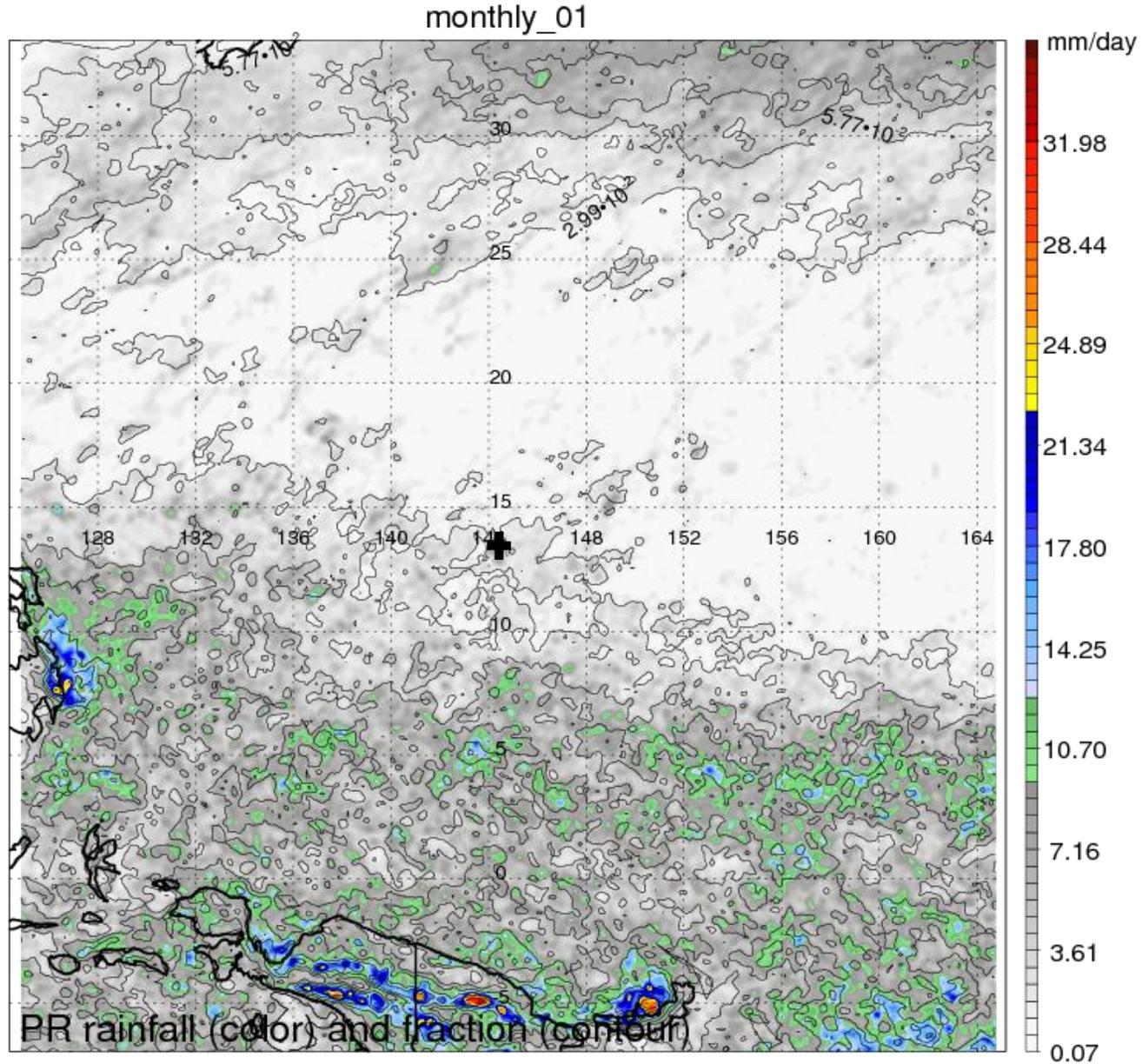
October, 2013

1998-2012 mean large circulation in January near Guam (ERA-Interim)

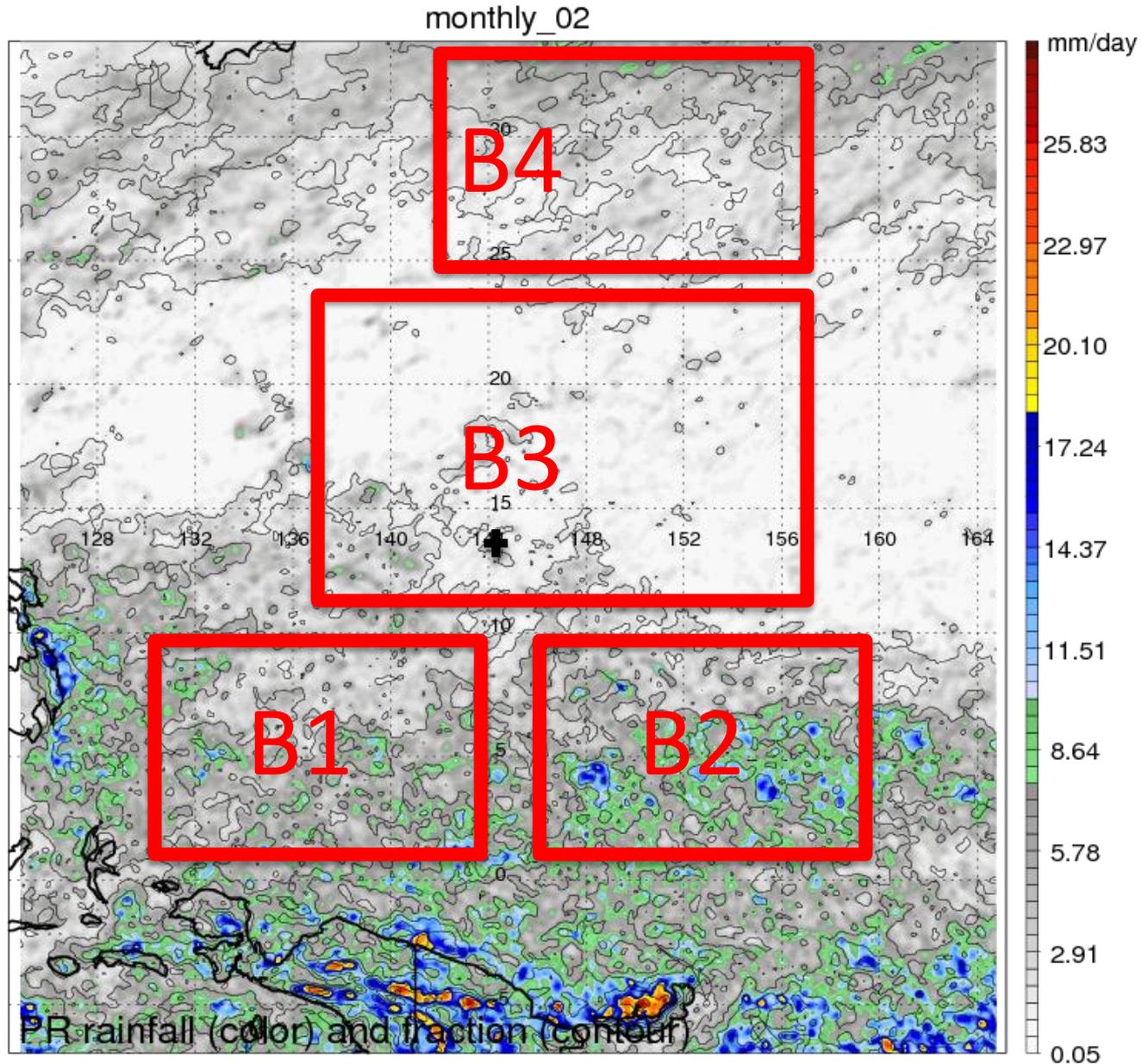


Warm color upward, cold color downward motion

January precipitation (TRMM radar climatology)

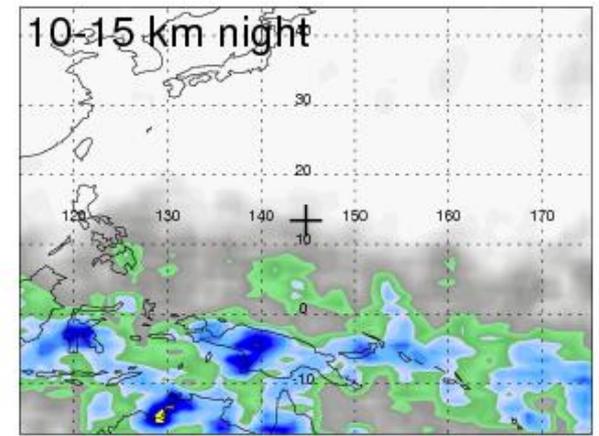
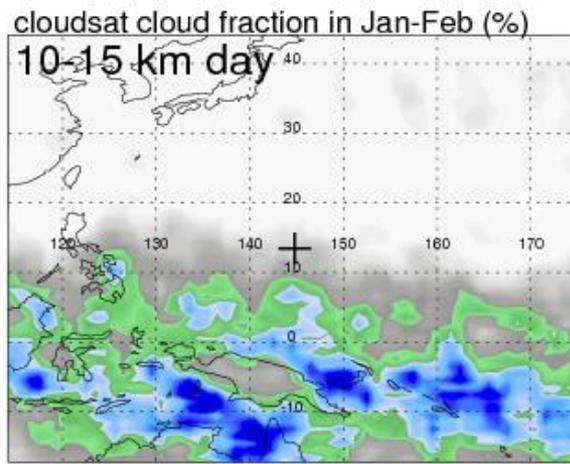


February precipitation (TRMM radar climatology)

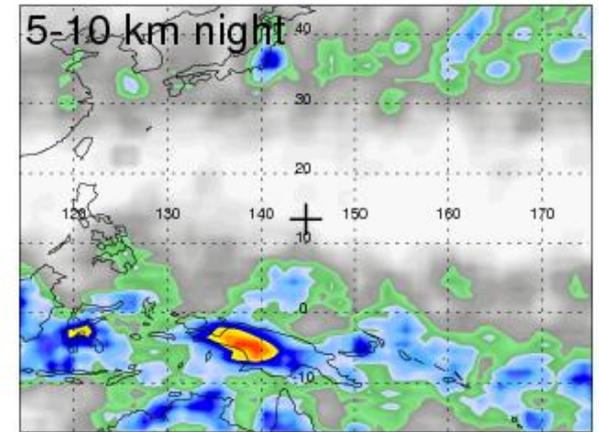
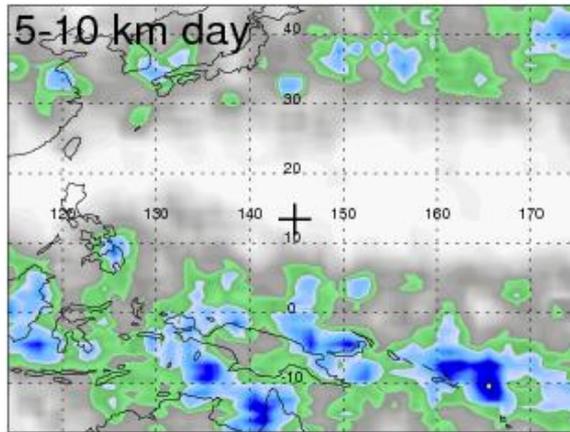


CloudSat
Cloud fraction

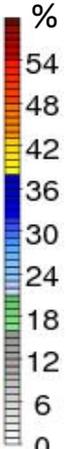
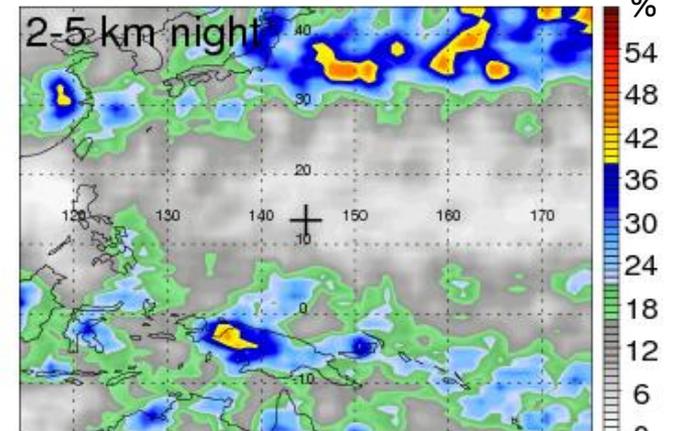
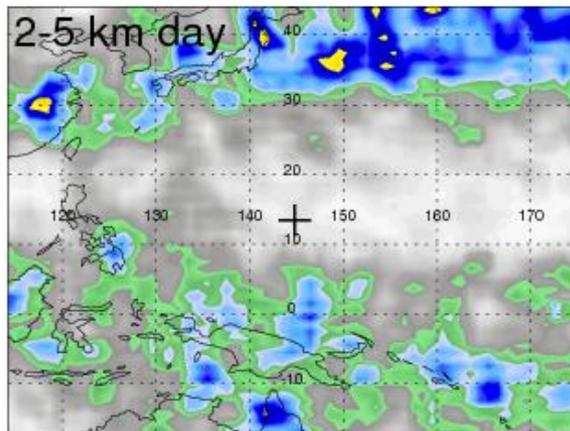
High clouds
10-15 km



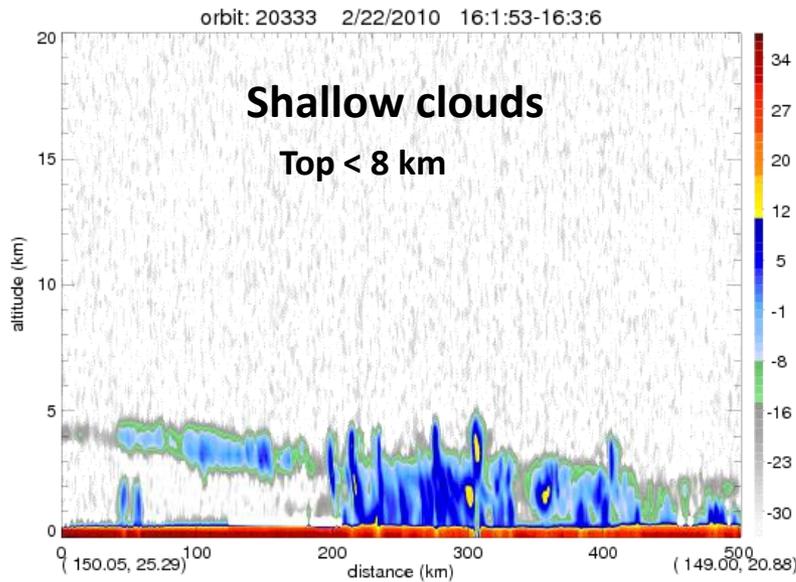
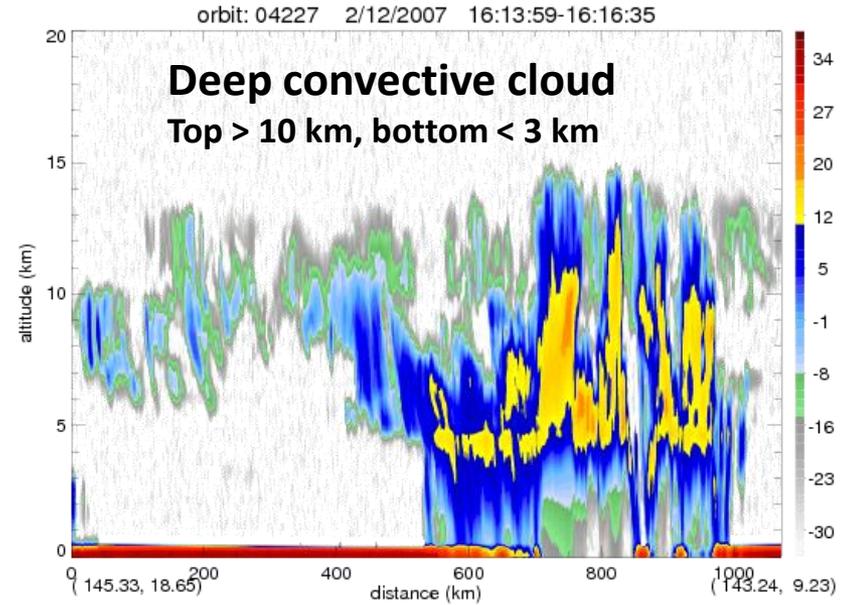
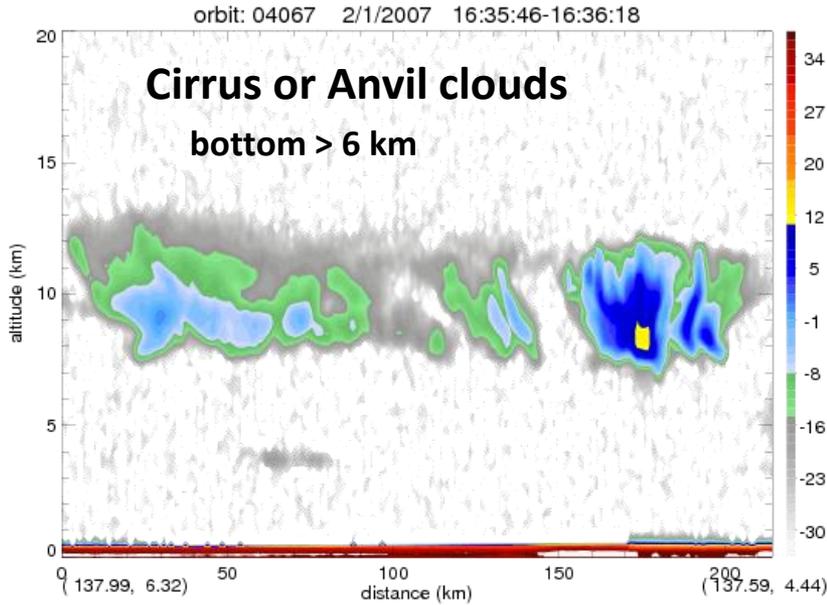
Mid-level clouds
5-10 km



Low clouds
2-5 km



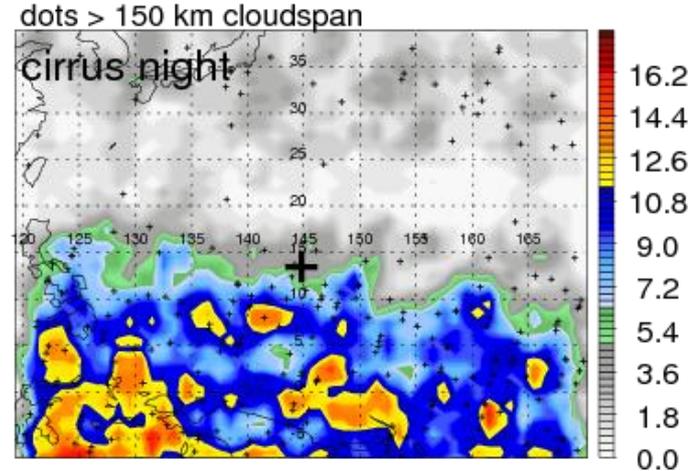
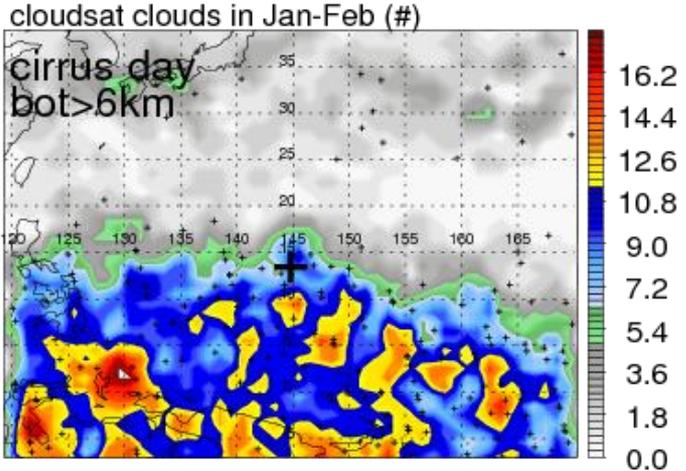
Definition of different types of clouds



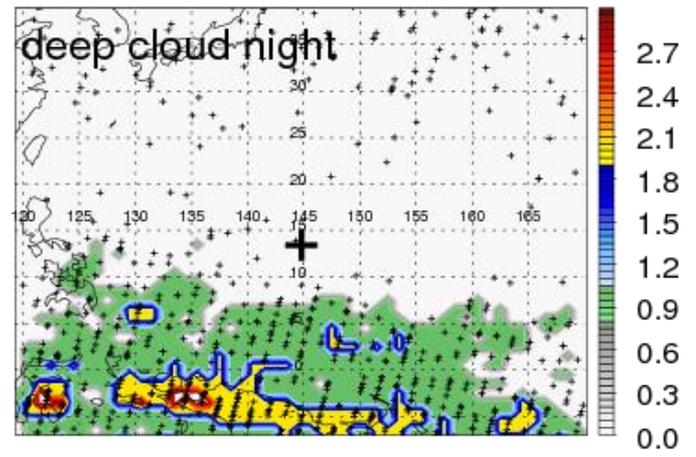
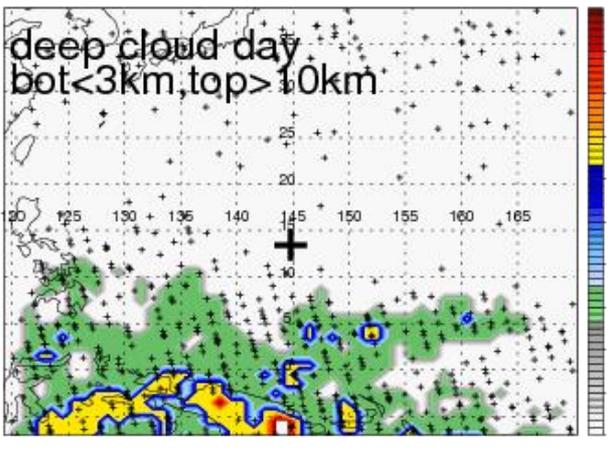
CloudSat

distribution of clouds in different types

Cirrus or anvil clouds
bottom > 6 km

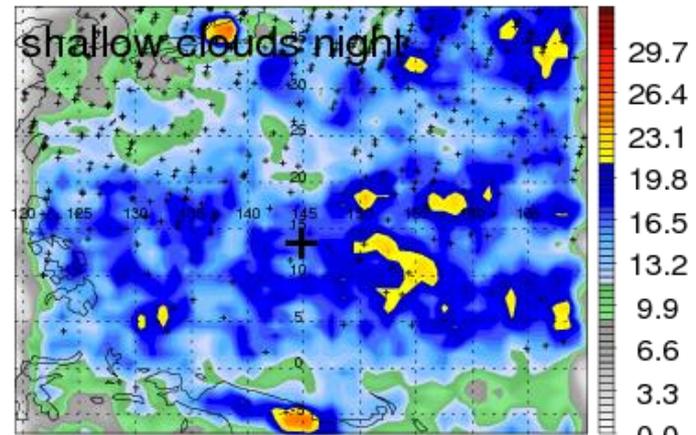
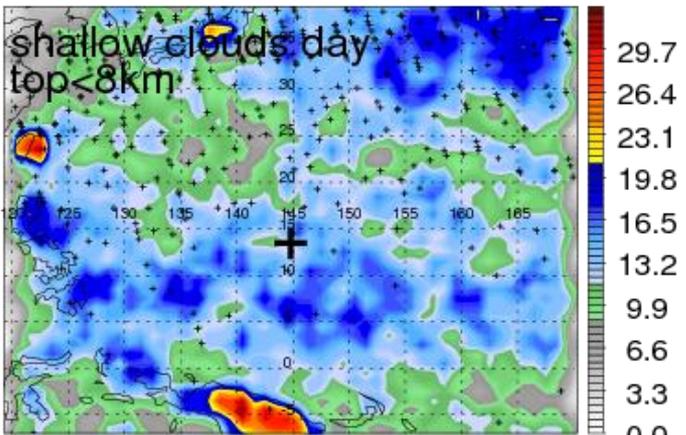


Deep clouds
Bottom < 3 km
Top > 10 km



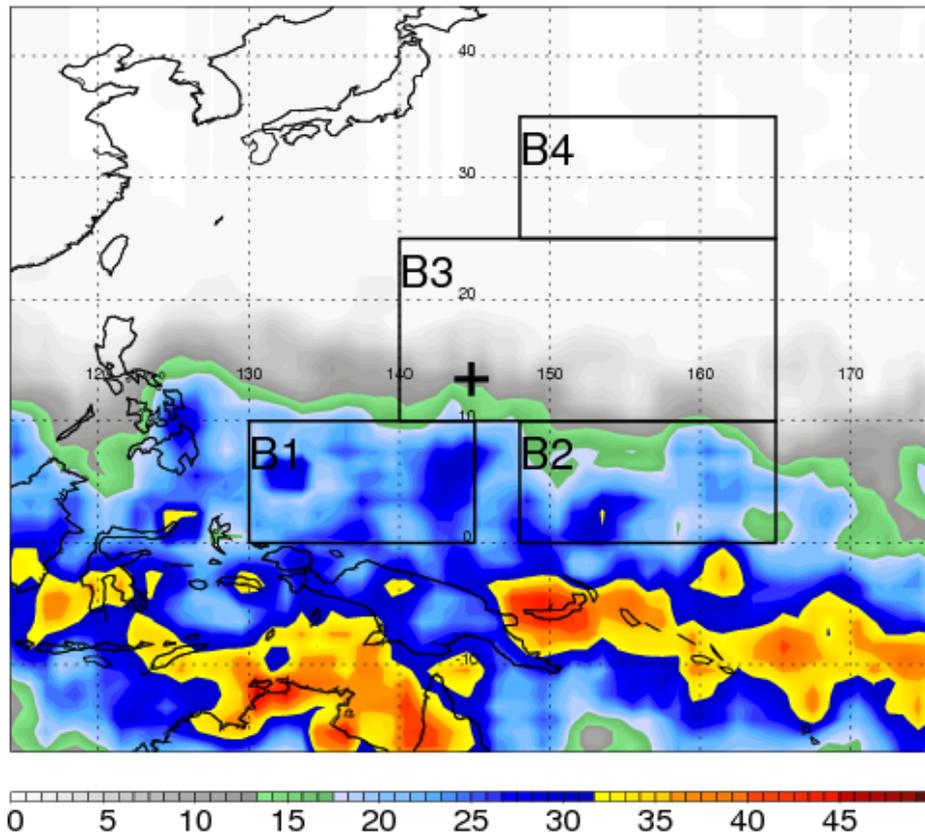
Shallow clouds
Top < 8 km

Black dots are clouds with horizontal size > 150 km

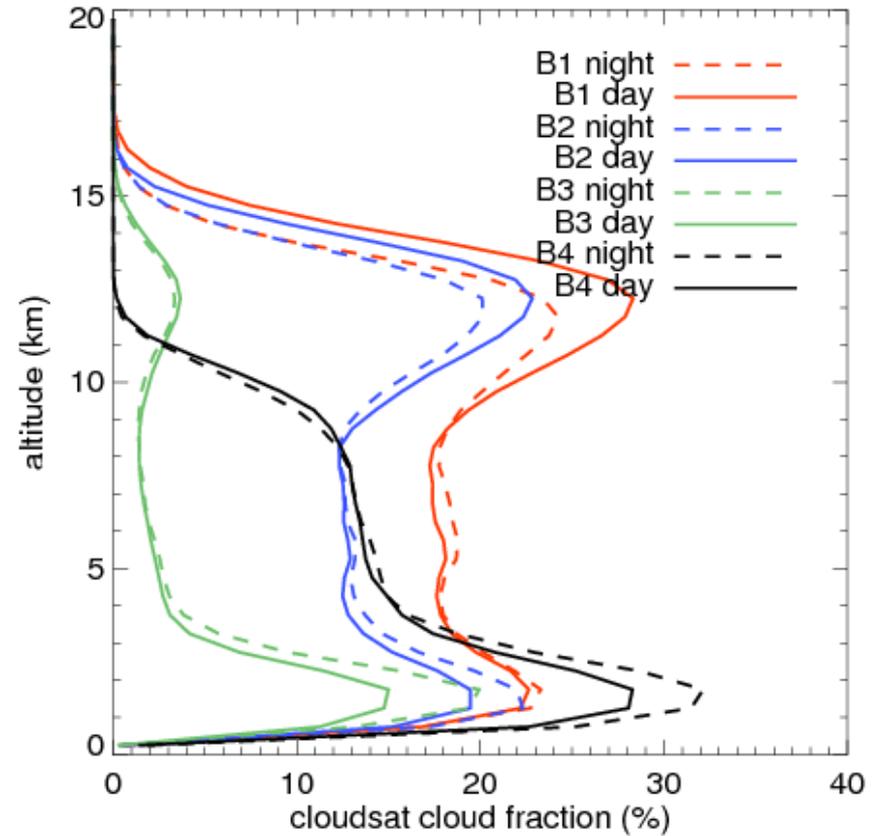


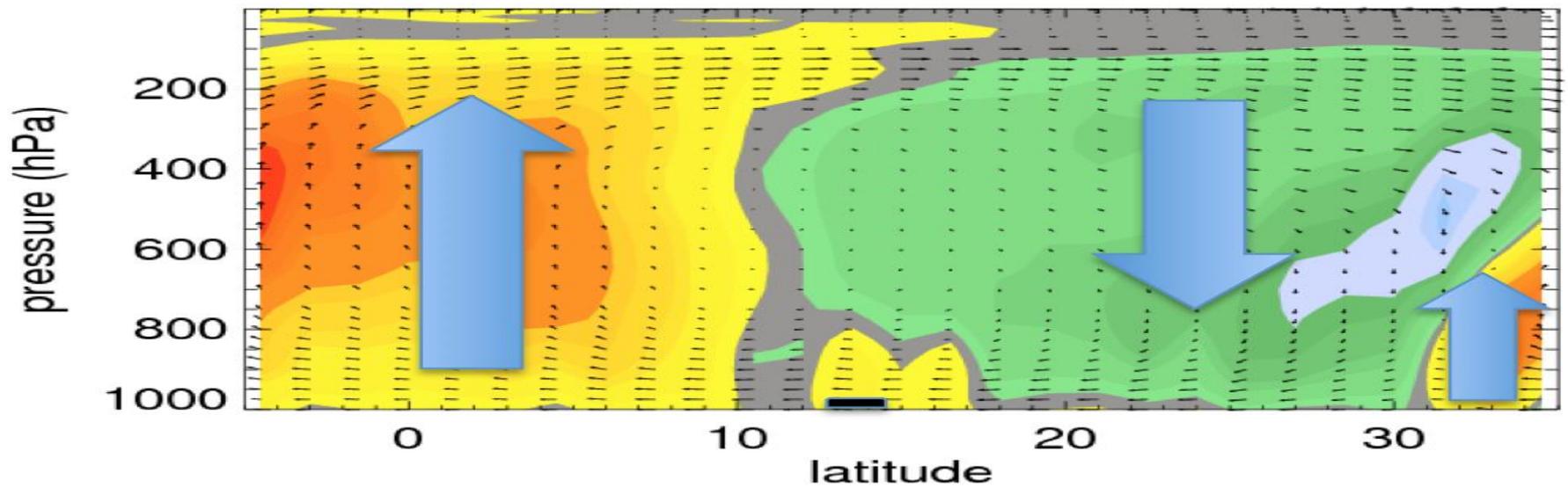
Cloud fraction in 4 different regions over ocean

CloudSat cloud fraction at 12.5-13 km in Jan-Feb

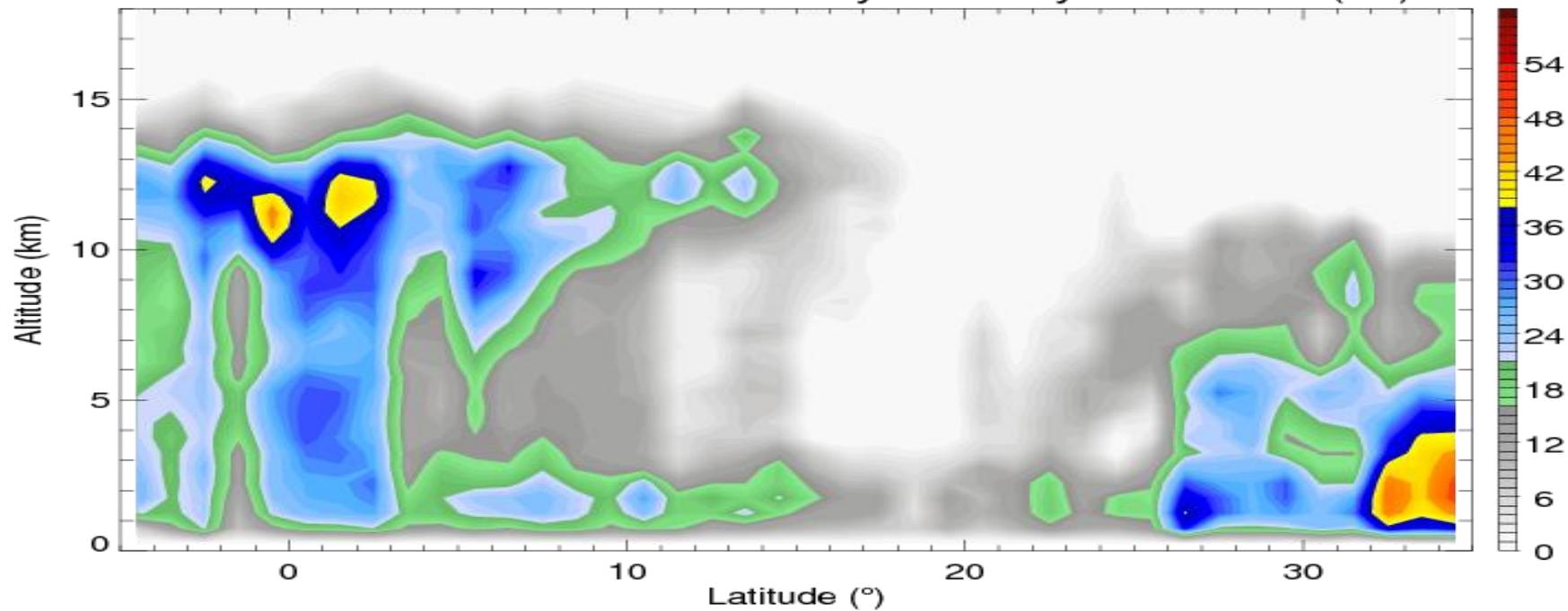


cloudsat cloud fraction in Jan-Feb





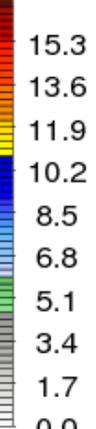
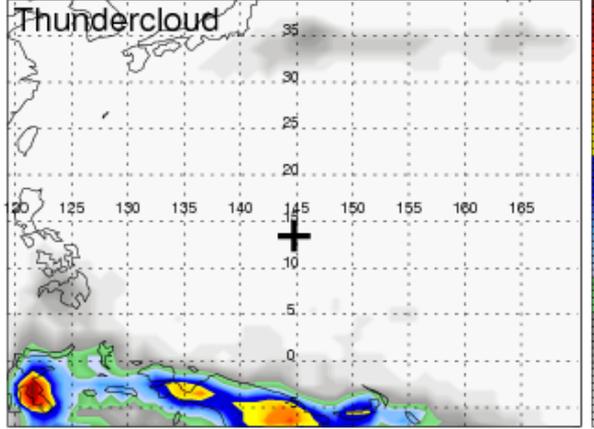
CloudSat cloud fraction in January-February at 144.5°W (%)



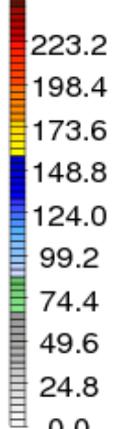
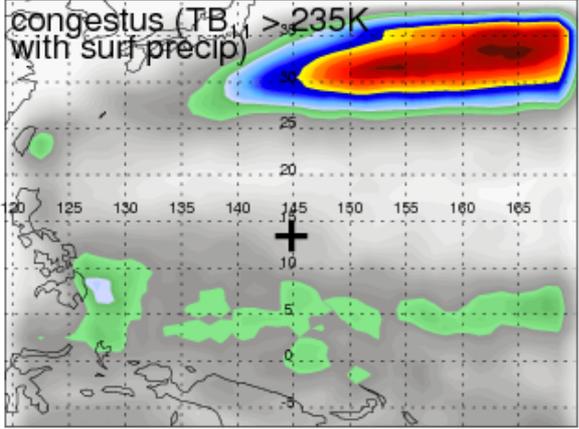
Definitions of cloud types from TRMM

- **Thunder clouds**
systems with lightning observed by LIS
- **Deep convection**
radar reflectivity echo top (precipitation size particles) reaching 12 km
- **Intense convection**
radar reflectivity of 40 dBZ at 6 km (likely hail)
- **Congestus clouds**
Cloud top temperature $< 0^{\circ}\text{C}$ and $> -38^{\circ}\text{C}$, with surface rainfall
- **Non-raining ice clouds**
Cloud top temperature $< 0^{\circ}\text{C}$ but without surface rainfall
- **Warm rain**
Cloud top temperature $> 0^{\circ}\text{C}$ with surface rainfall

TRMM observed clouds in Jan-Feb (#)

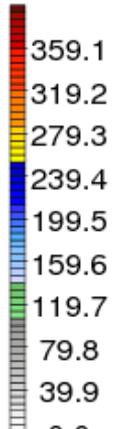
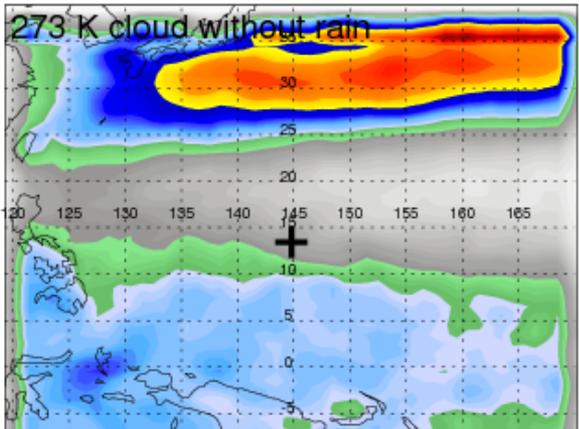
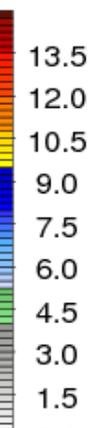
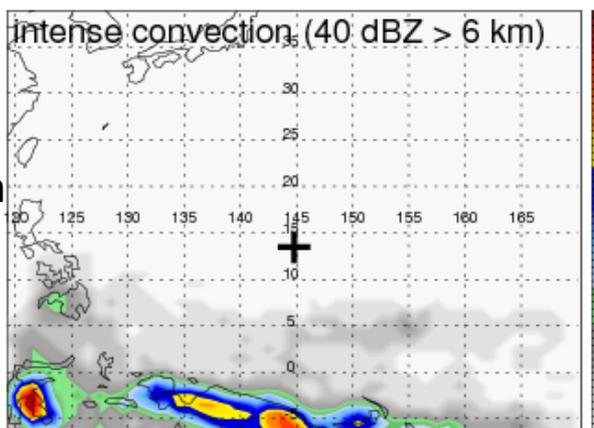
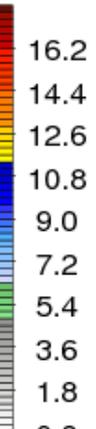
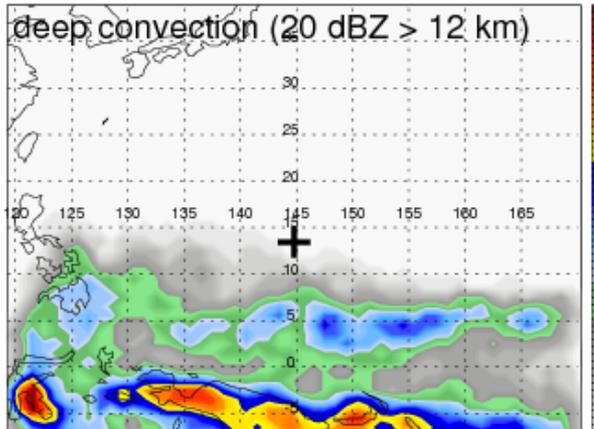


dots > 2000 km²



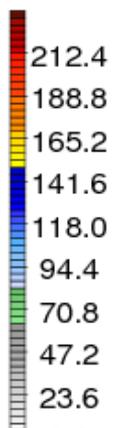
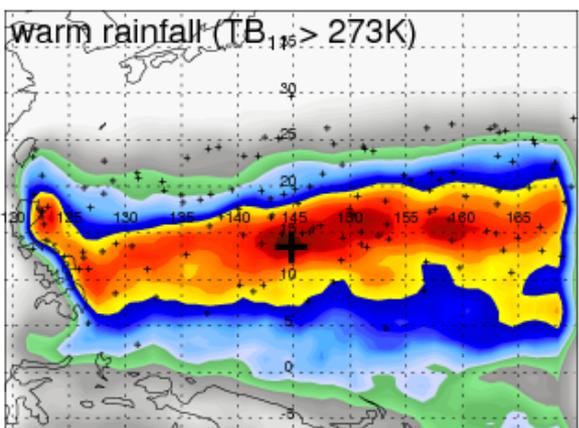
Congestus

273K clouds
min TB11 > 235 K
With sfc rain



non-raining
Ice clouds

273K clouds
no rain by PR

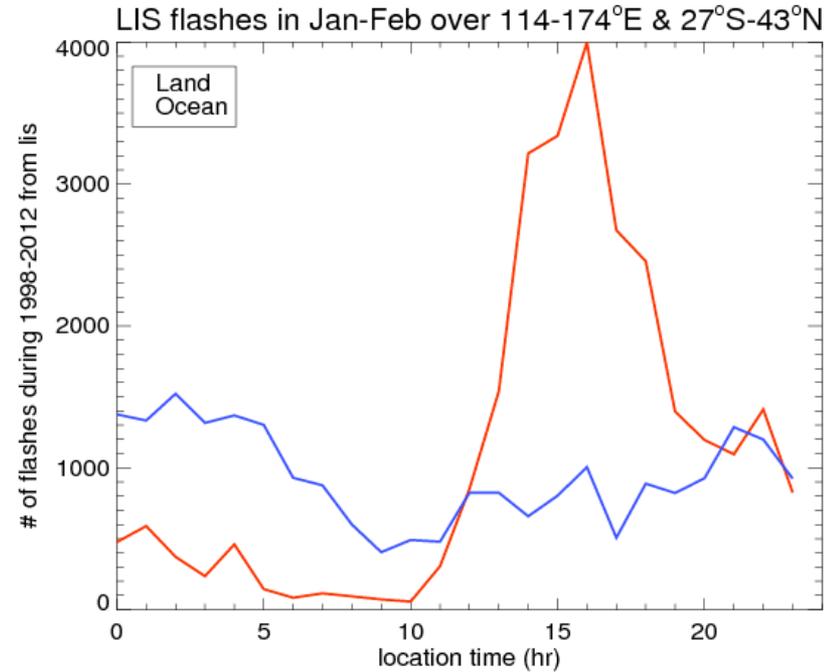
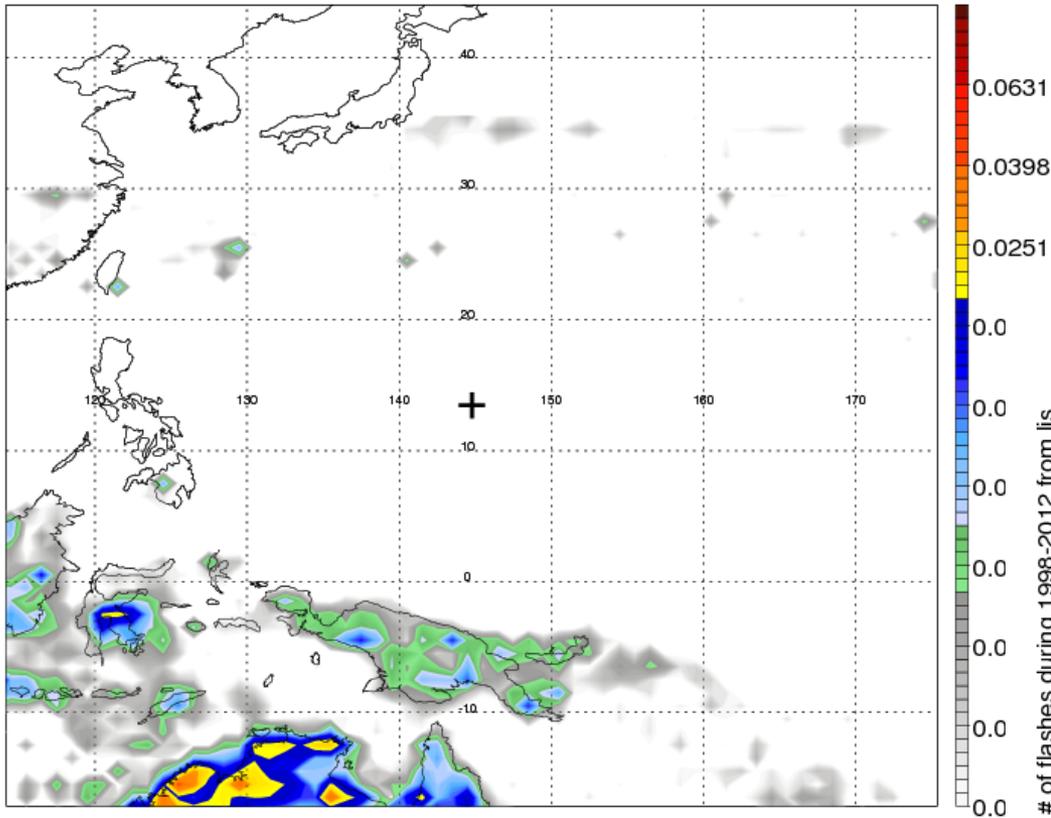


Warm rain

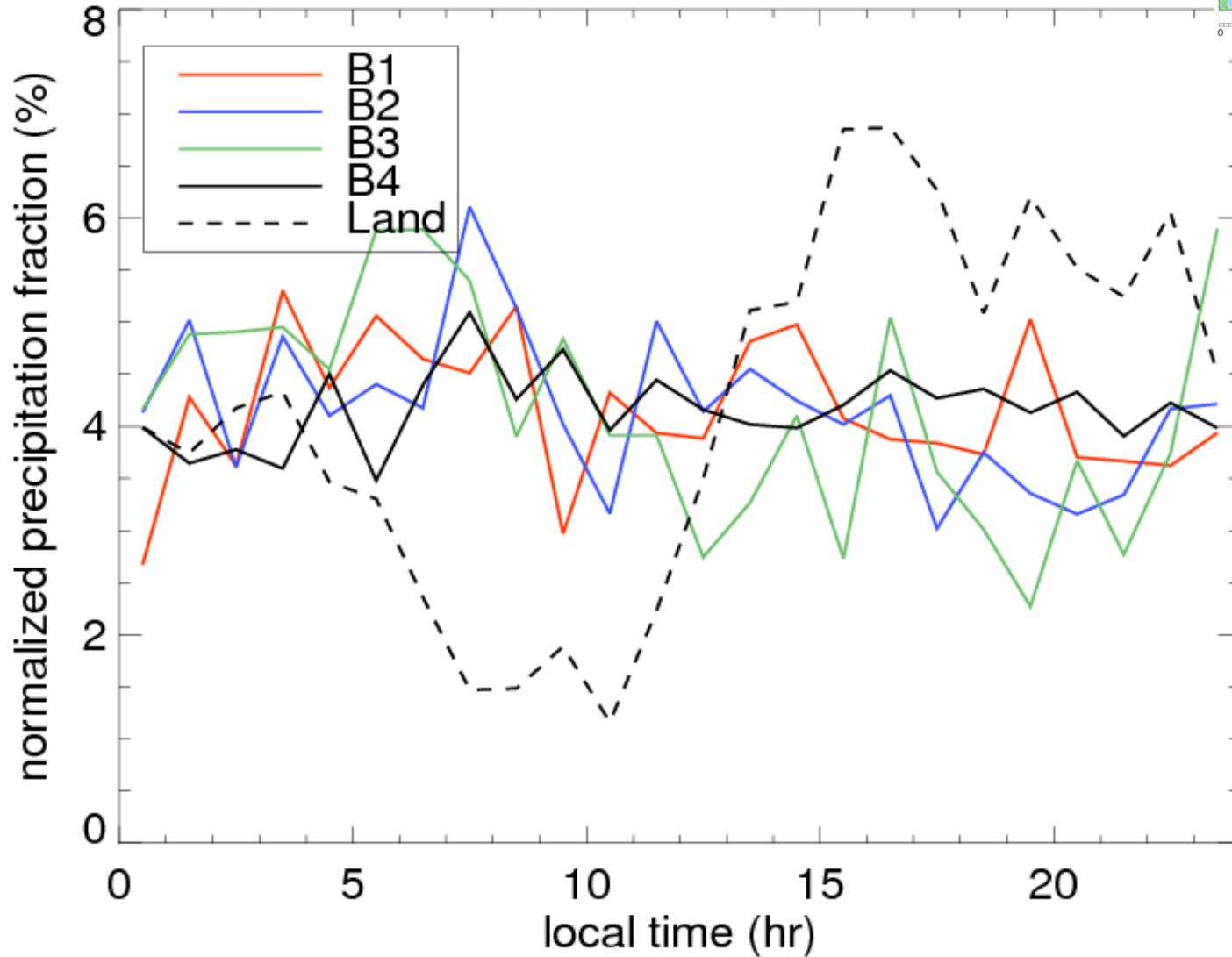
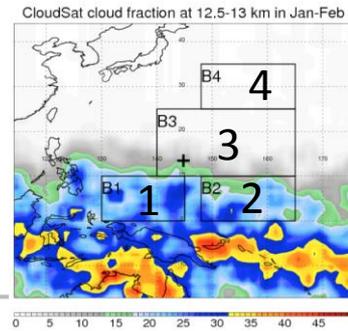
min TB11 > 273 K
Black dots > 2000 km²

Lightning

Lightning occurrence in Jan-Feb (#/1 degree box/sec)



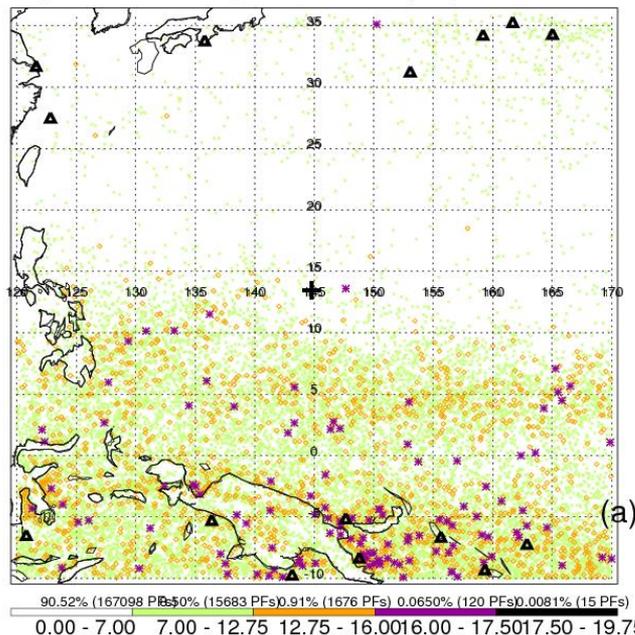
Diurnal variation - Precipitation



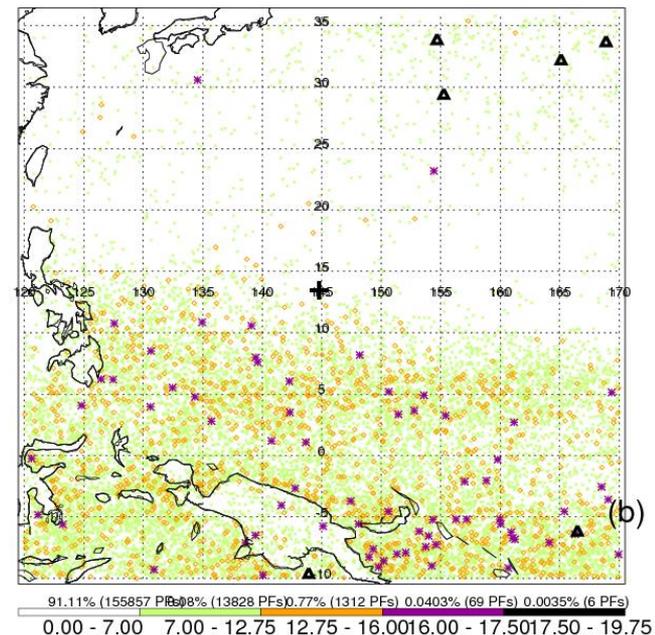
Depth of convection

(20 dBZ echo top)

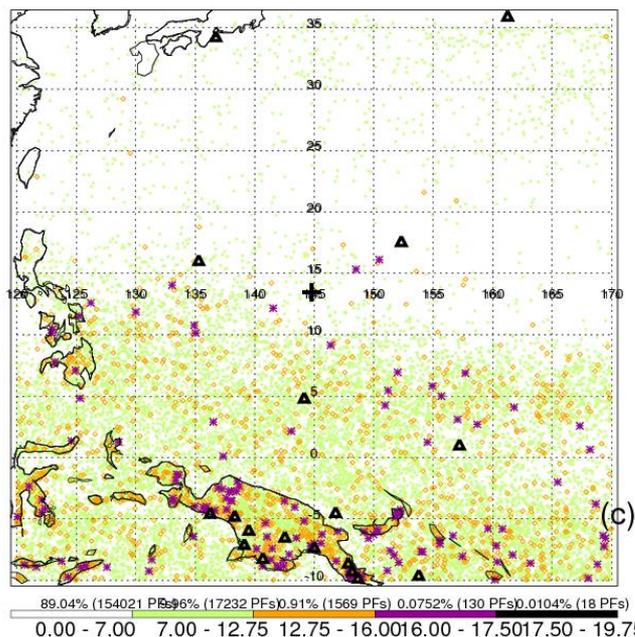
LT 00-06 locations of RPFs categorized by maximum height of 20 dBZ (km)



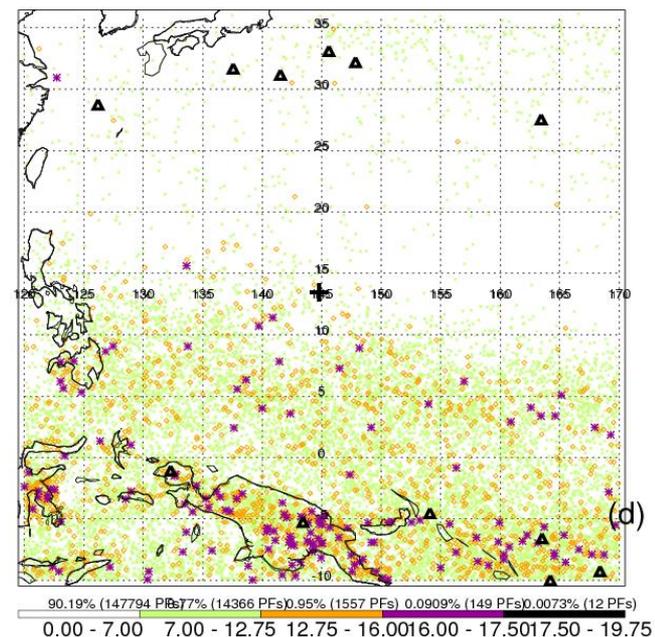
LT 06-12



LT 12-18



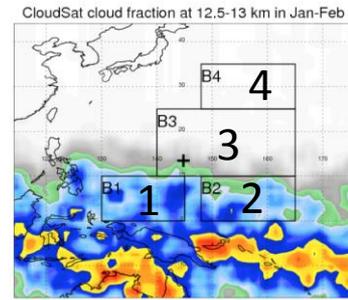
LT 18-24



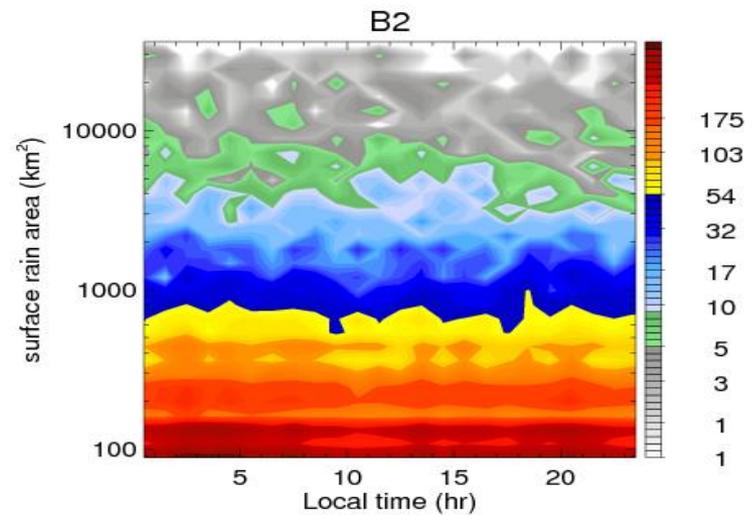
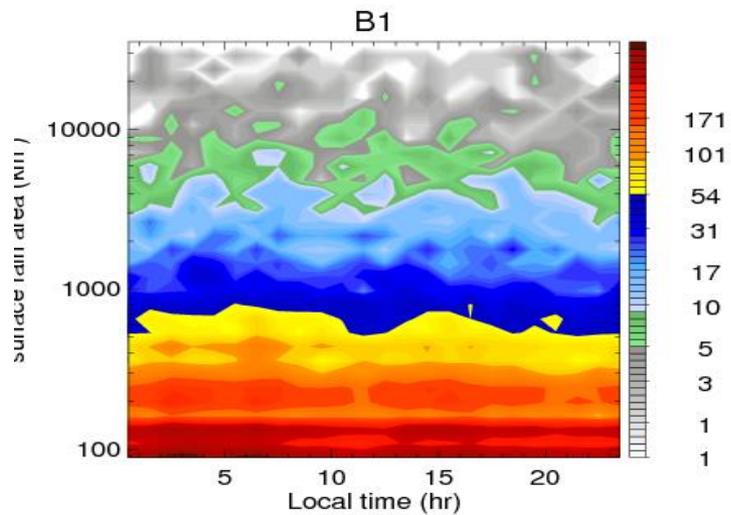
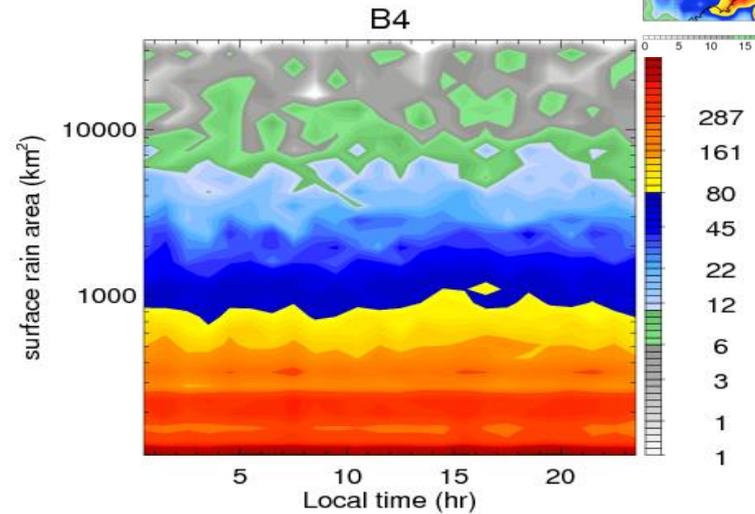
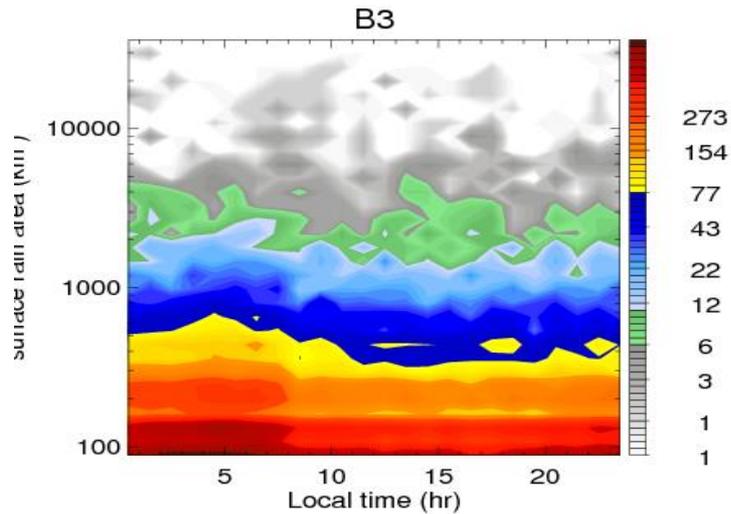
No change over ocean

Deeper in afternoon and early evening over land

Rain area vs. Local time (2D histogram)



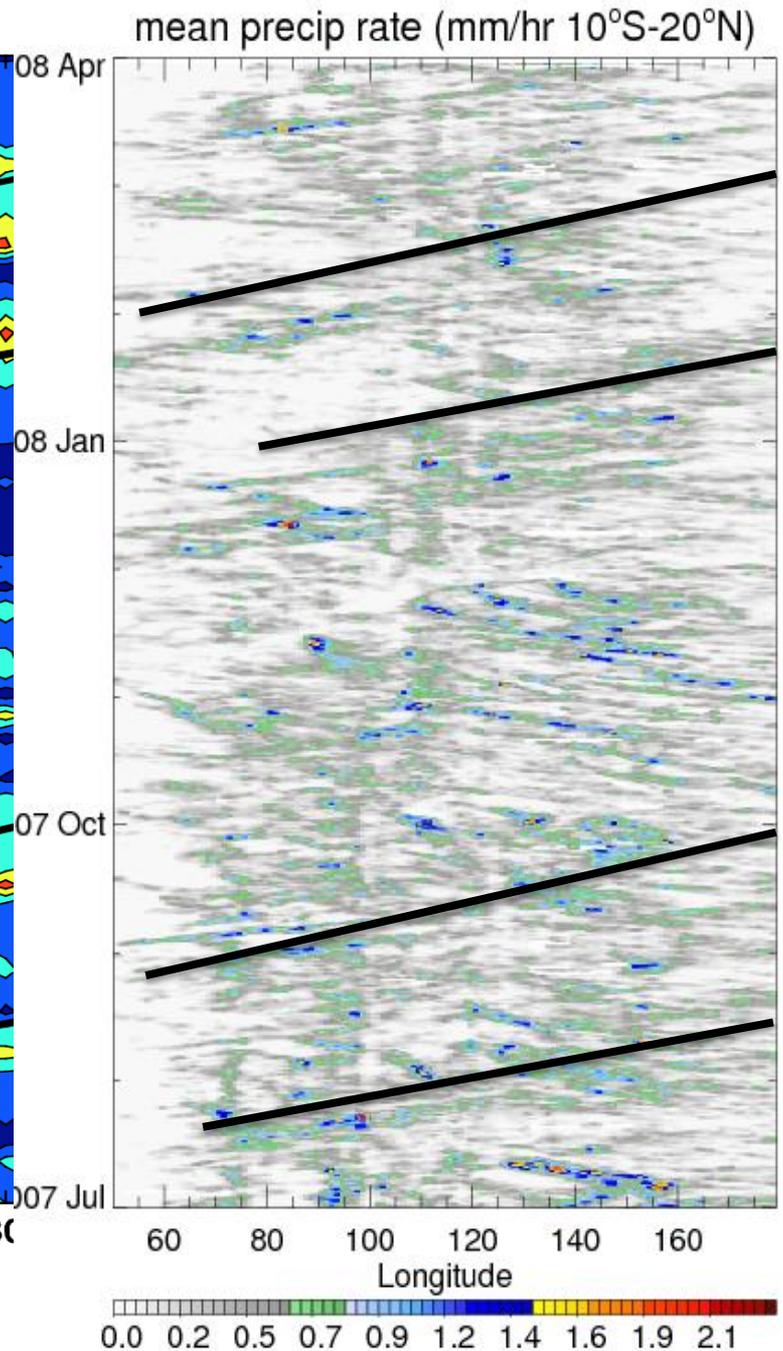
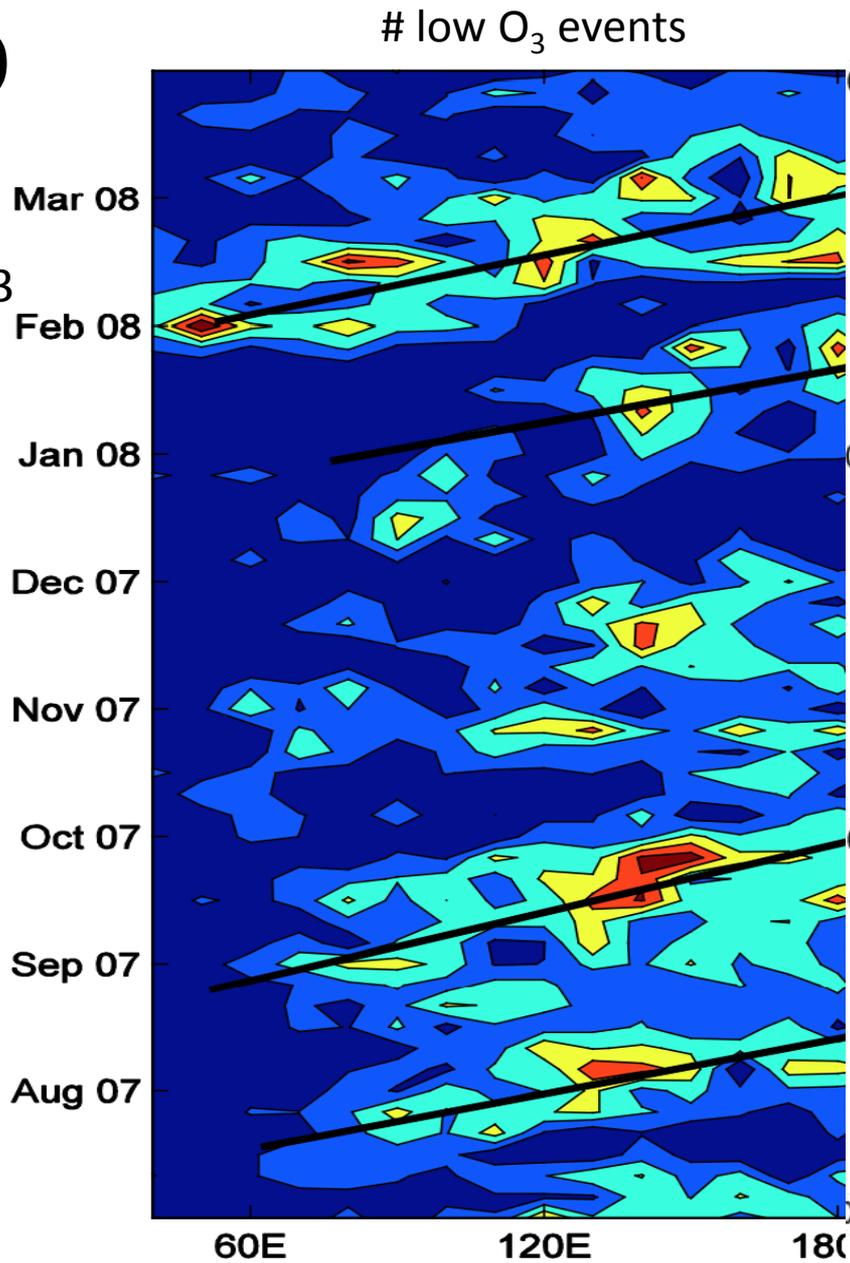
Rain
area



raining area are slightly bigger during night in B3 region

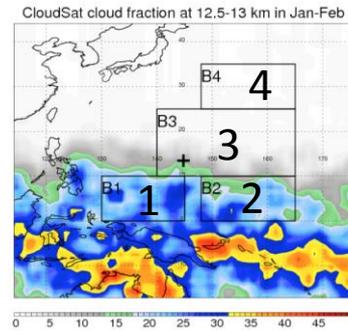
MJO

VS.
low O₃

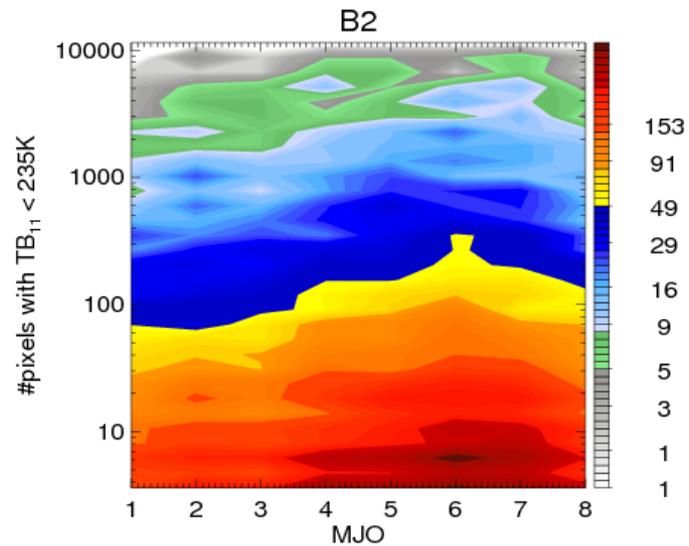
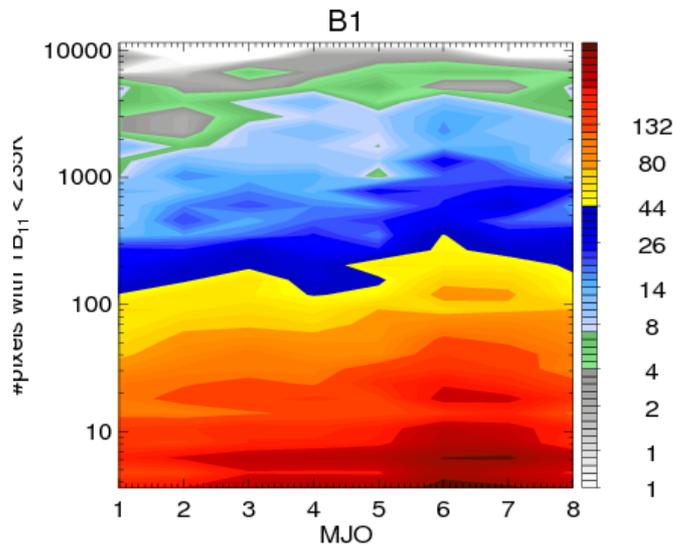
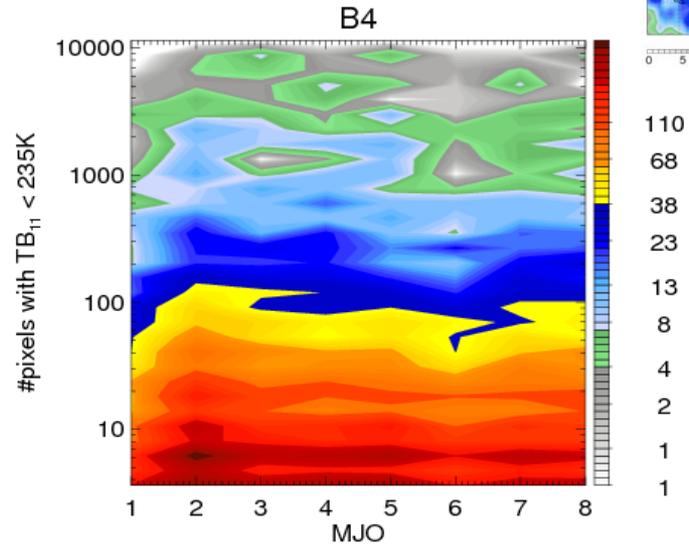
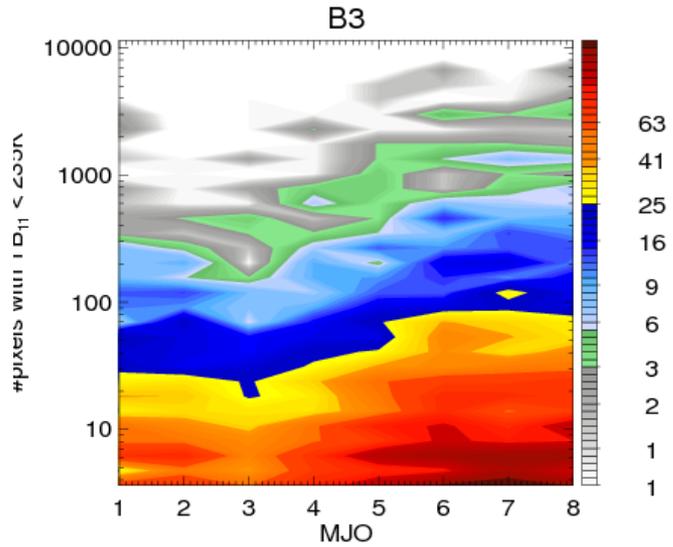


Cooper et al. 2013

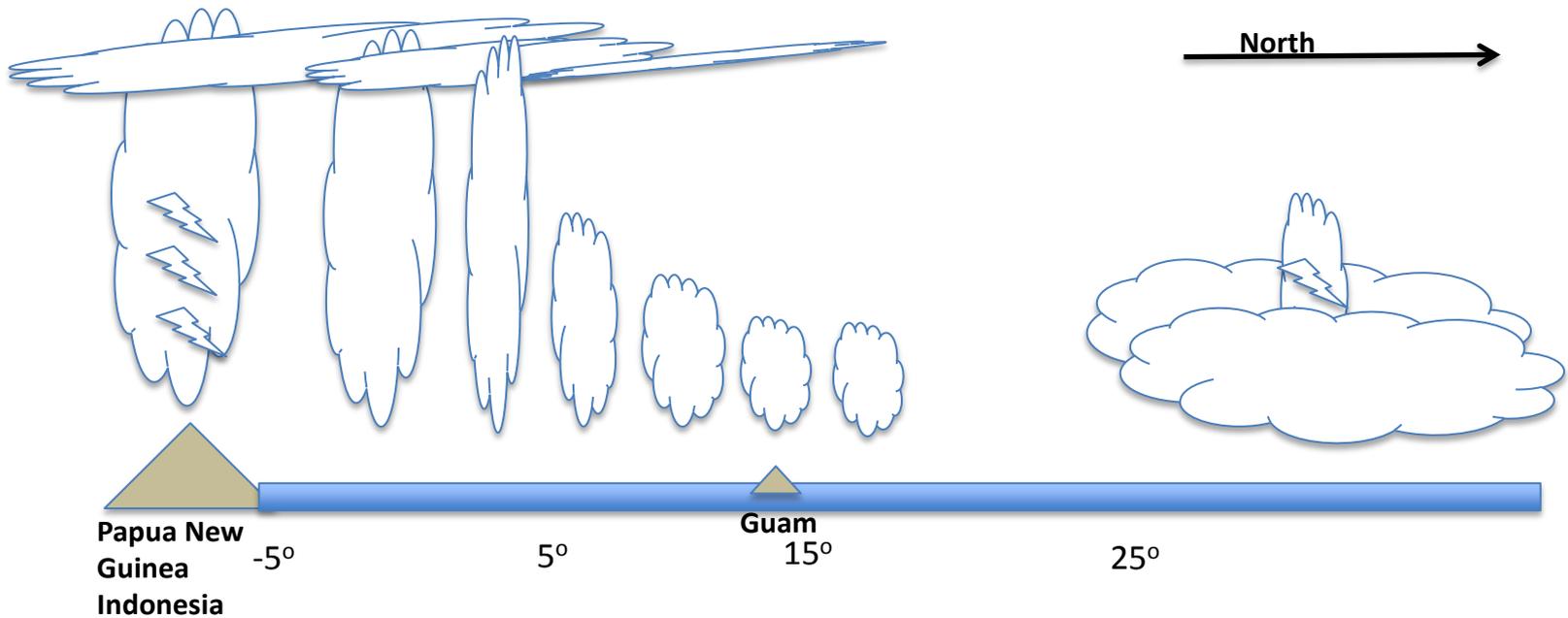
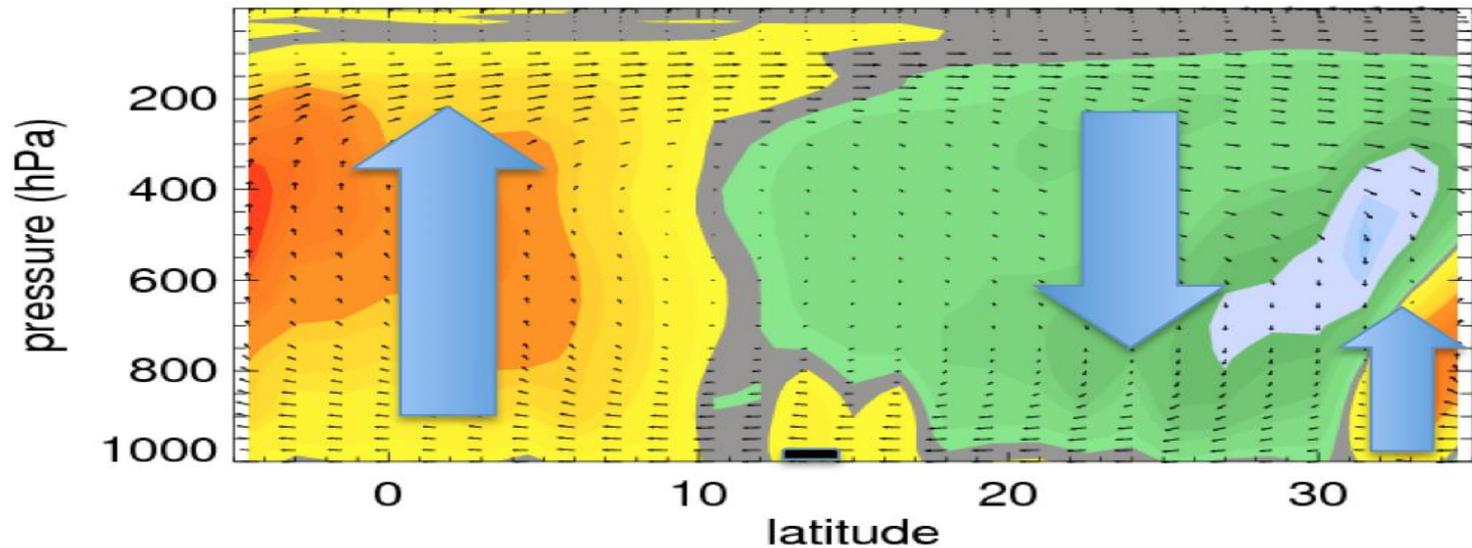
Cold cloud size vs. MJO phase (2D histogram)



Cold
cloud
Size



Summary: large scale circulation and clouds near Guam



Contrast: Land vs. Ocean

Cloud and precipitation over land and ocean near CONTRAST region in Jan and Feb are quite different:

	Land	Ocean
Convective intensity	Strong	Weak
Lightning	Frequent	Rare
Diurnal variation	Strong, peak afternoon	Weak, slight peak in early morning
Cirrus/anvil	Same/close to	Same/close to
MJO	Relatively less variation	Weak period in phase 4, stronger in phase 6-7

Contrast: north vs. South ocean

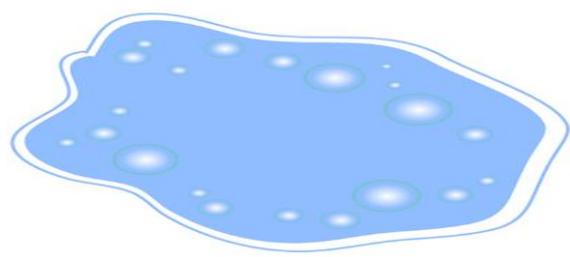
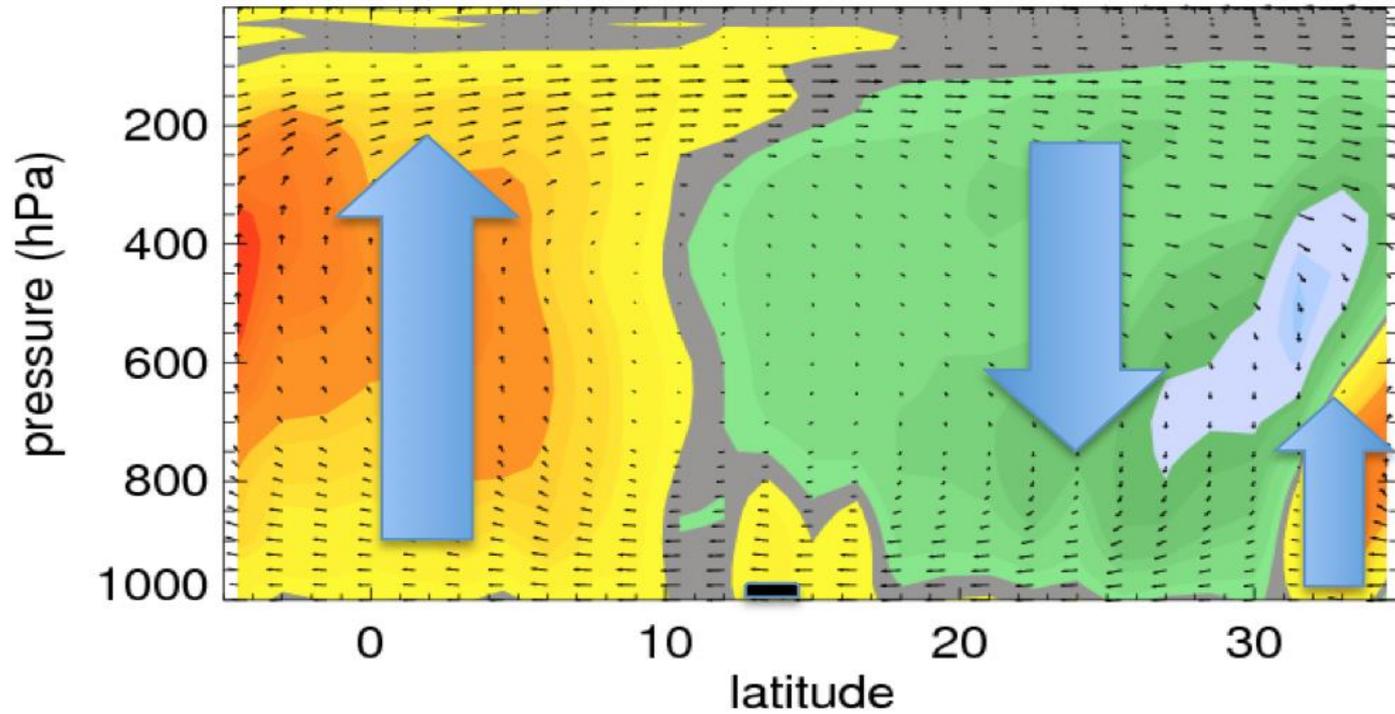
Focus on ocean, cloud and precipitation over north and south of Guam are quite different.

	North	South
Cloud Depth	Shallow	Deep
Cirrus/anvil at high levels (> 10 km)	Rare	Relative frequent
Deep convection	Rare	happens
Non-rain cloud	More	Relatively less
Congestus	More	Relatively less
Warm rainfall	Mainly near Guam	
Diurnal variation	Typical oceanic weak diurnal cycle peak in early morning	Weak diurnal cycle, but with some land convection influences
Lightning	rare but sometimes over ocean	Very rare

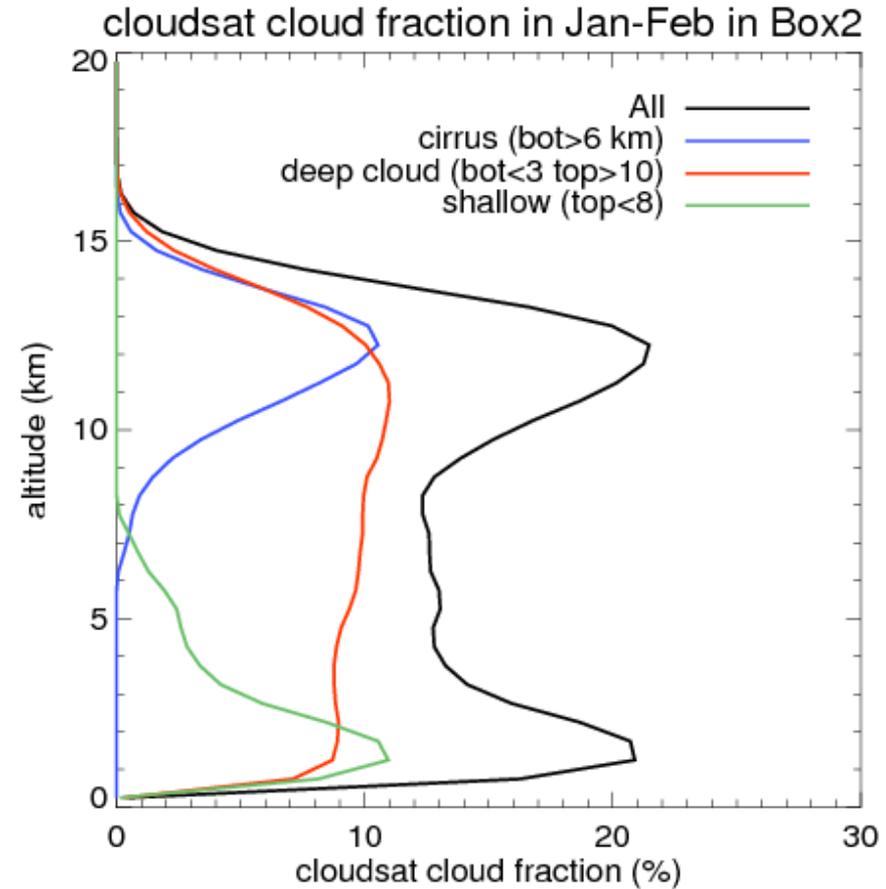
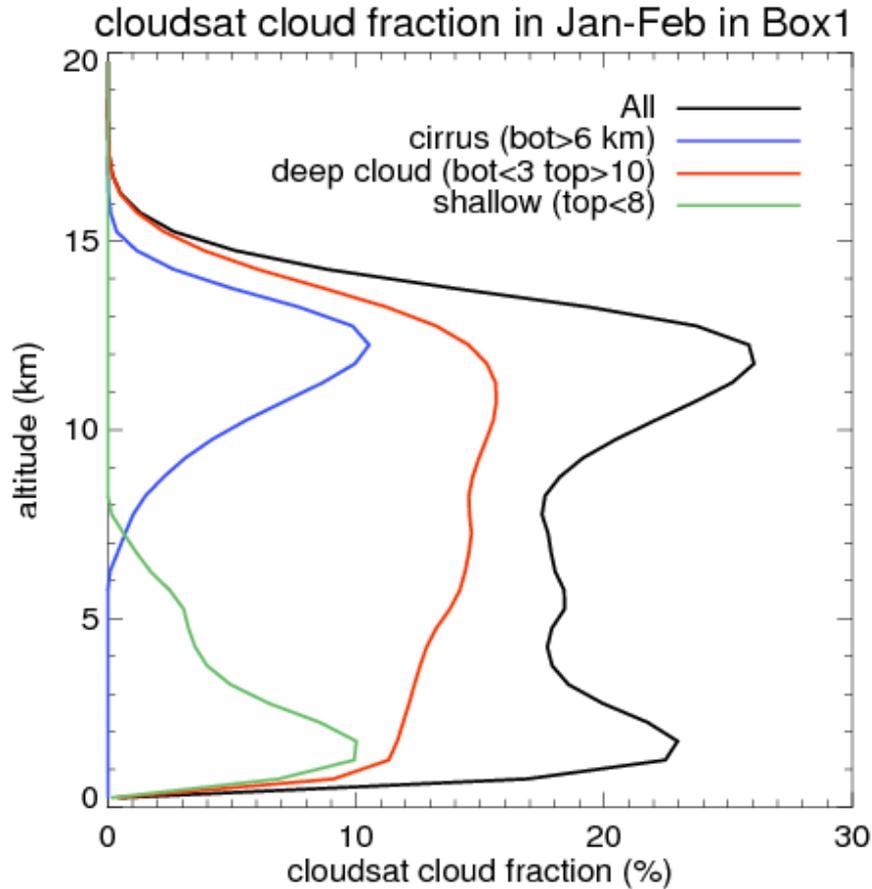
Contrast: Southeast vs. Southwest Ocean

	Southwest	Southeast
Cloud Depth	deep over both regions	
High clouds	Higher fraction	Relatively lower fraction
High cloud detached from convection	about the same at 10% occurrence	
High cloud attached to convection	More (15%)	Less (10%)
Tot precipitation	Relatively less	Relatively more (20%)
Shallow clouds	Day = night	Day < night
MJO	6-7 active	6-8 active
Diurnal variation	Slight diurnal peak of cold cloud area in early morning	Very weak diurnal cycle
Land impact	More	Less

Questions?



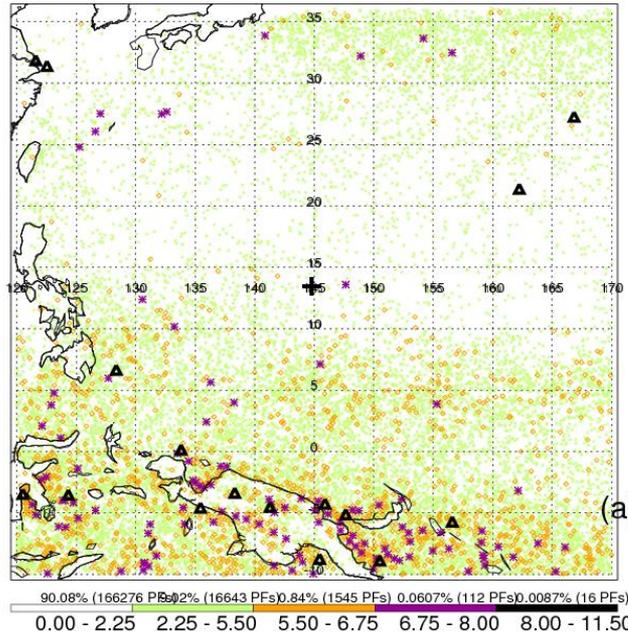
Difference between B1 and B2 in vertical profiles of clouds



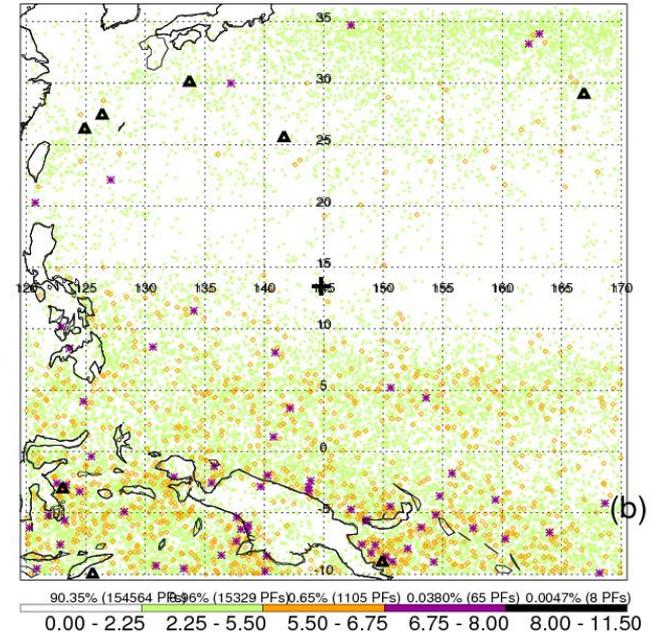
Convective intensity

40 dBZ echo top height

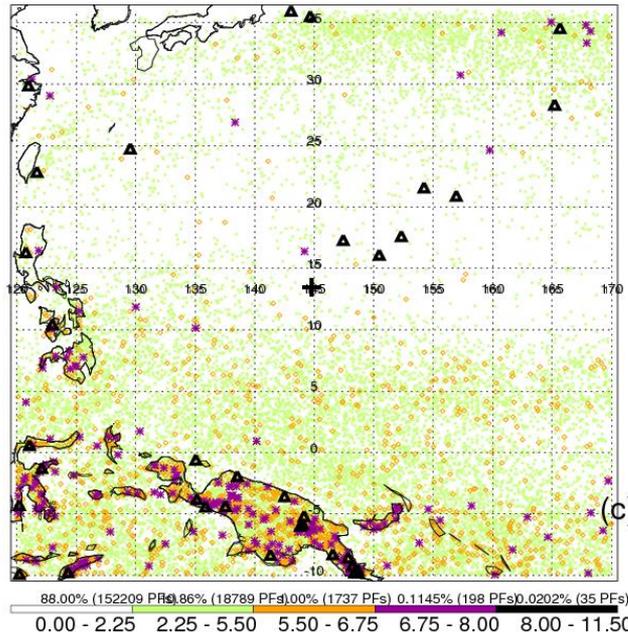
LT 00-06 locations of RPFs categorized by maximum height of 40 dBZ (km)



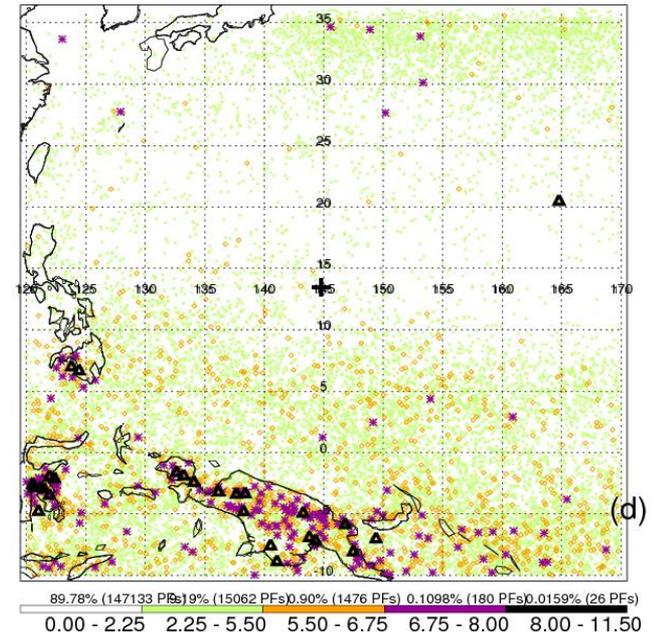
LT 06-12



LT 12-18



LT 18-24

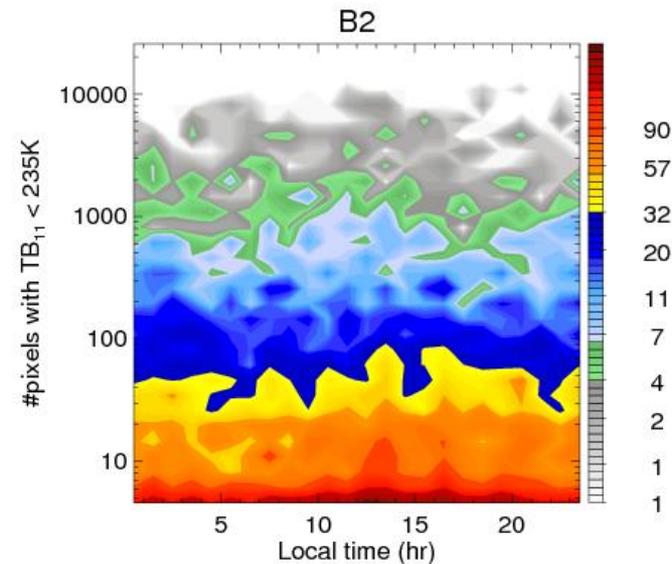
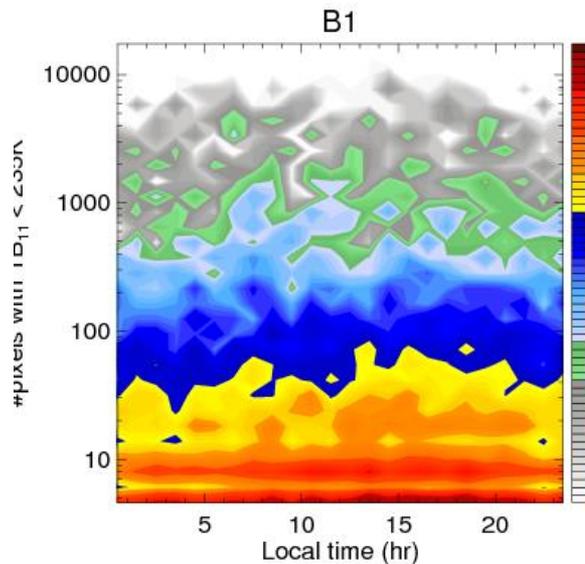
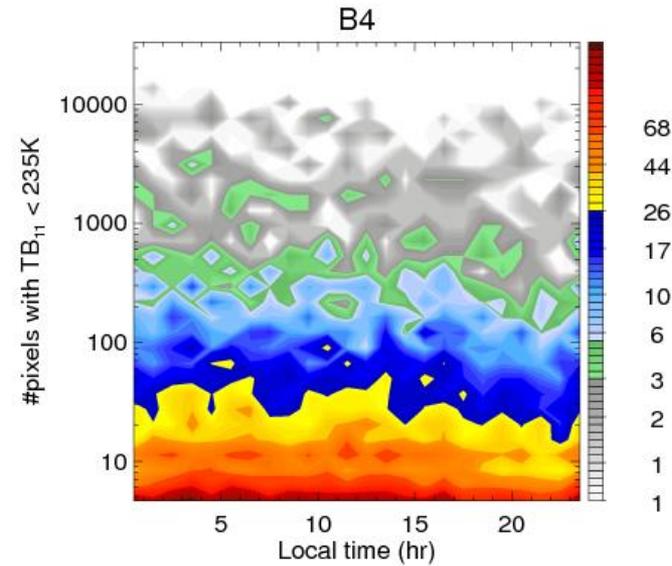
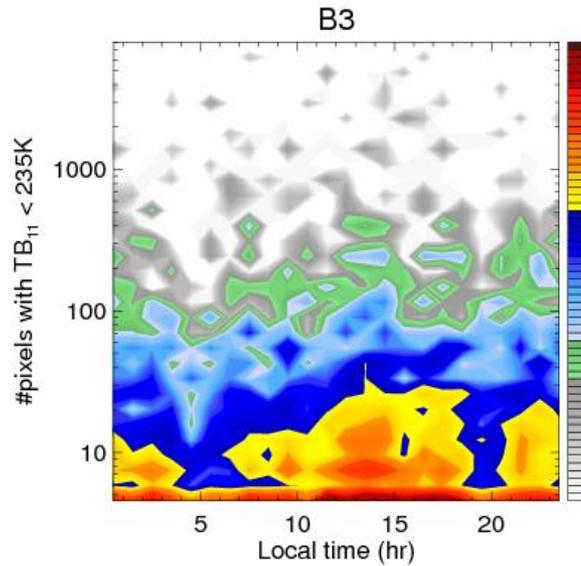


No change over ocean

Stronger in afternoon and early evening over land

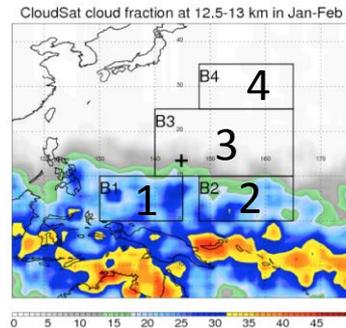
Cold cloud size vs. Local time (2D histogram)

Cold
cloud
Size

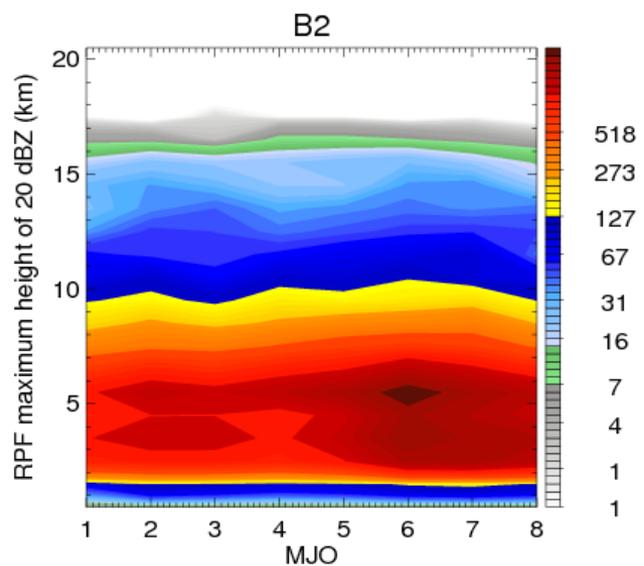
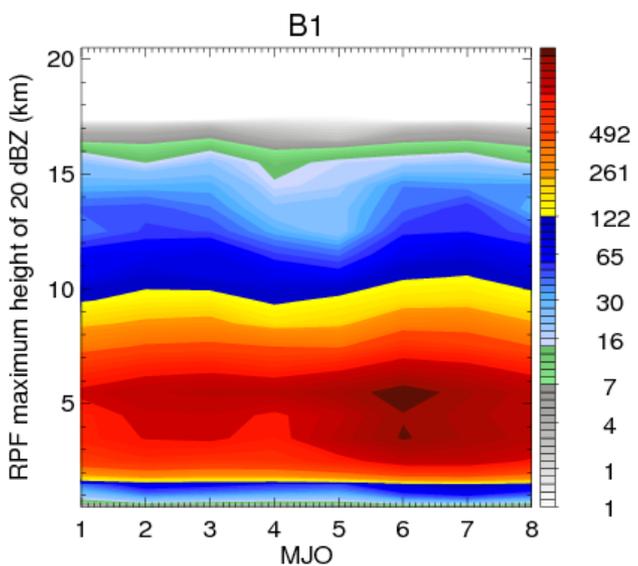
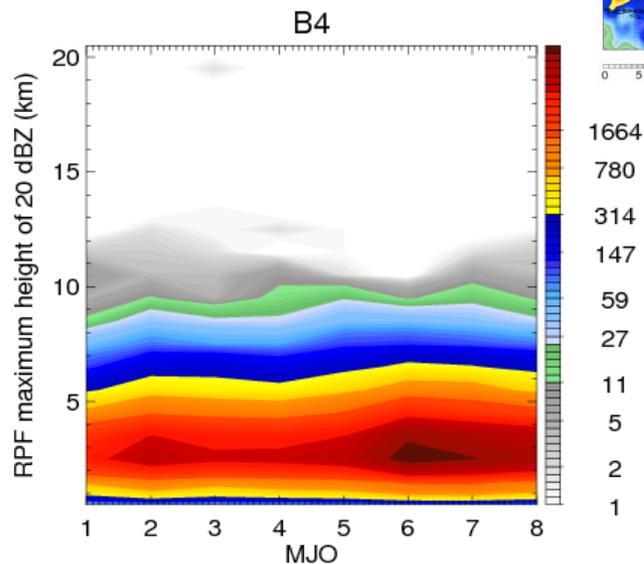
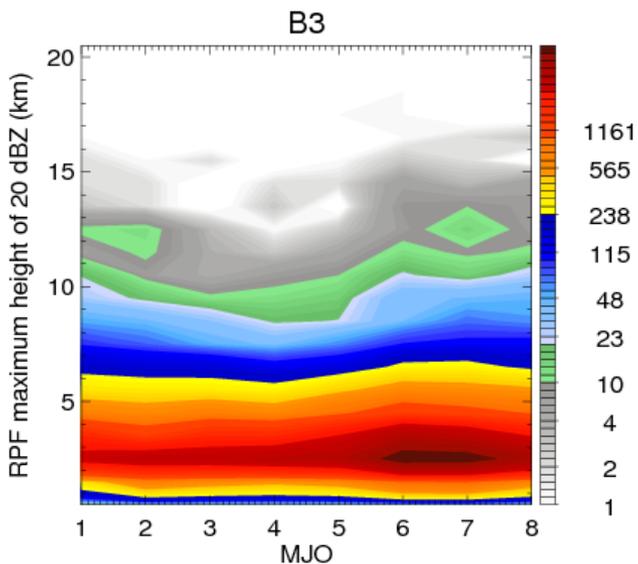


Afternoon peaks of cold cloud in B1 and B3 likely associated with anvil of deep convection over land

Depth vs. MJO phase (2D histogram)

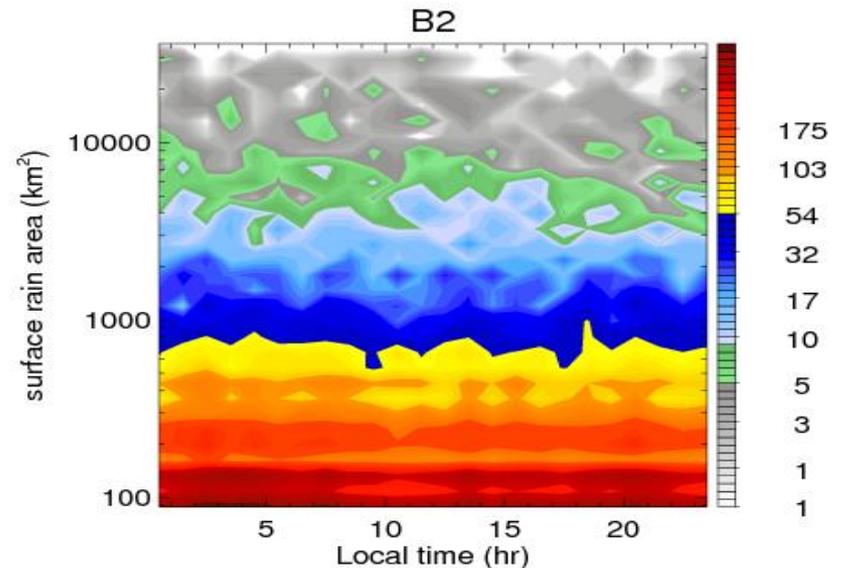
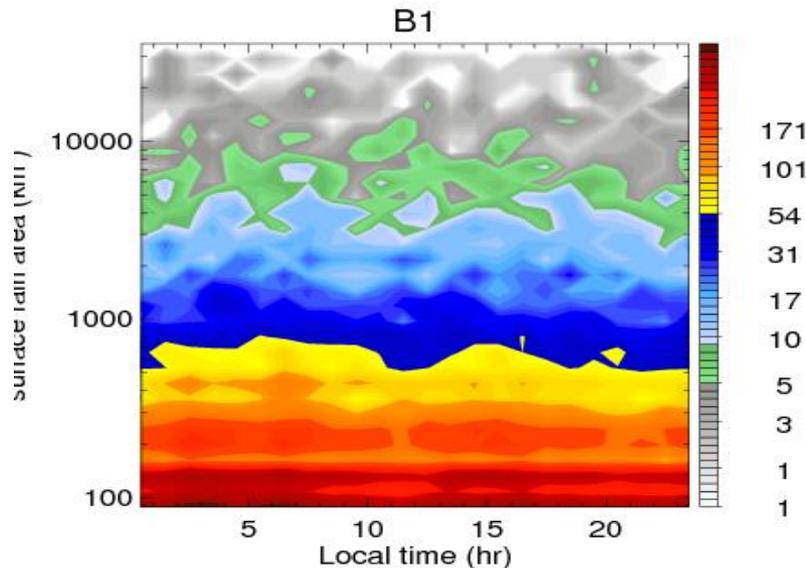
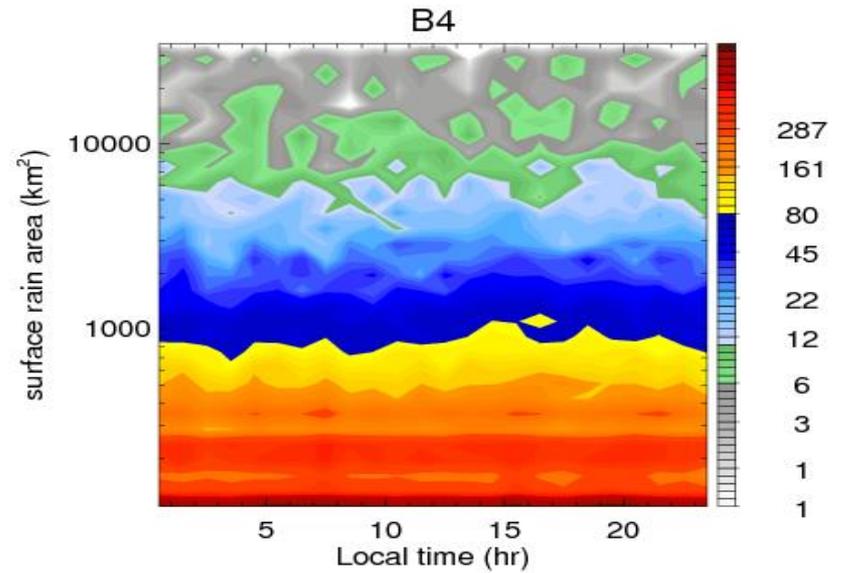
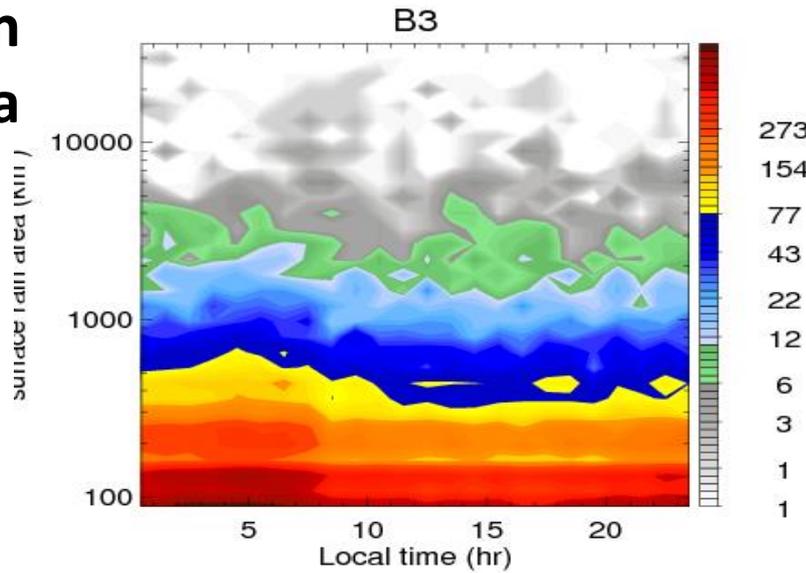


Echo
top
height



Rain area vs. Local time (2D histogram)

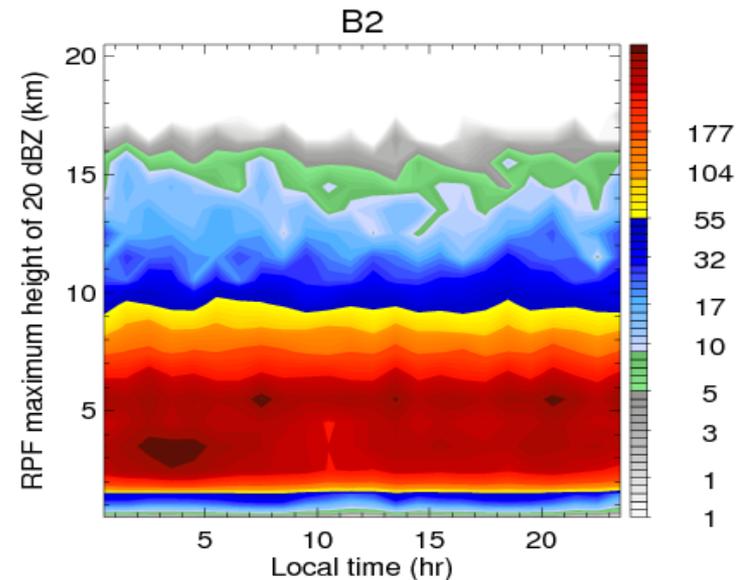
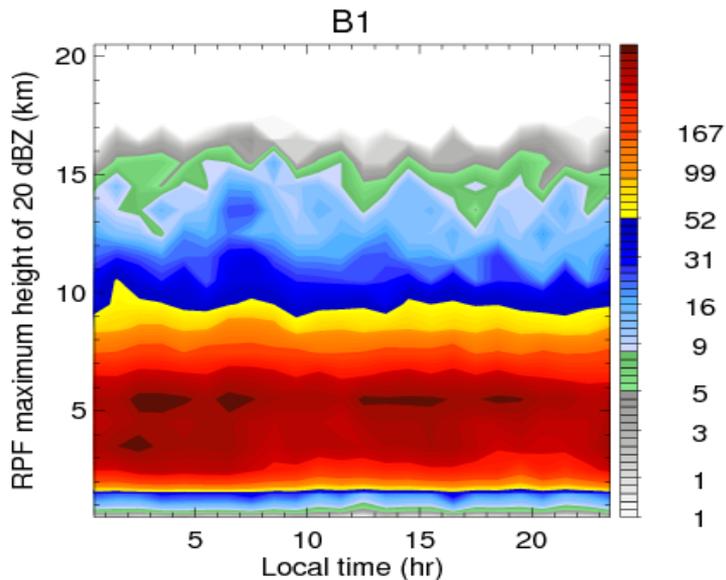
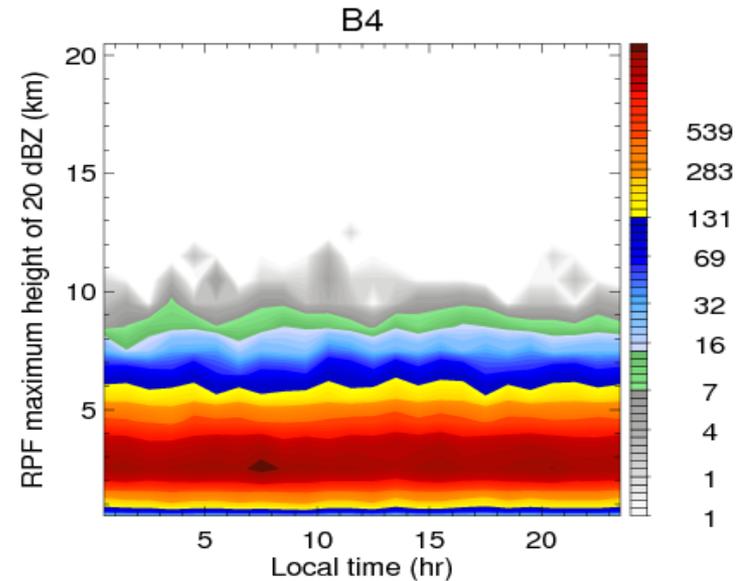
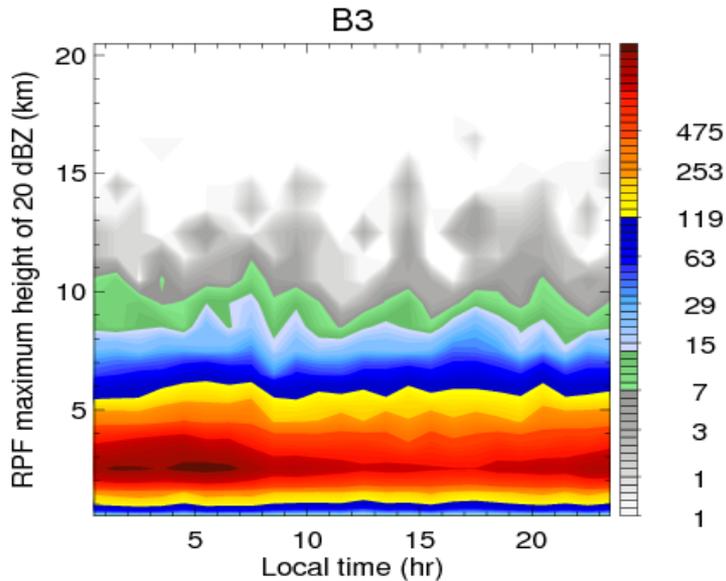
Rain
area



raining area are slightly bigger during night in B3 region

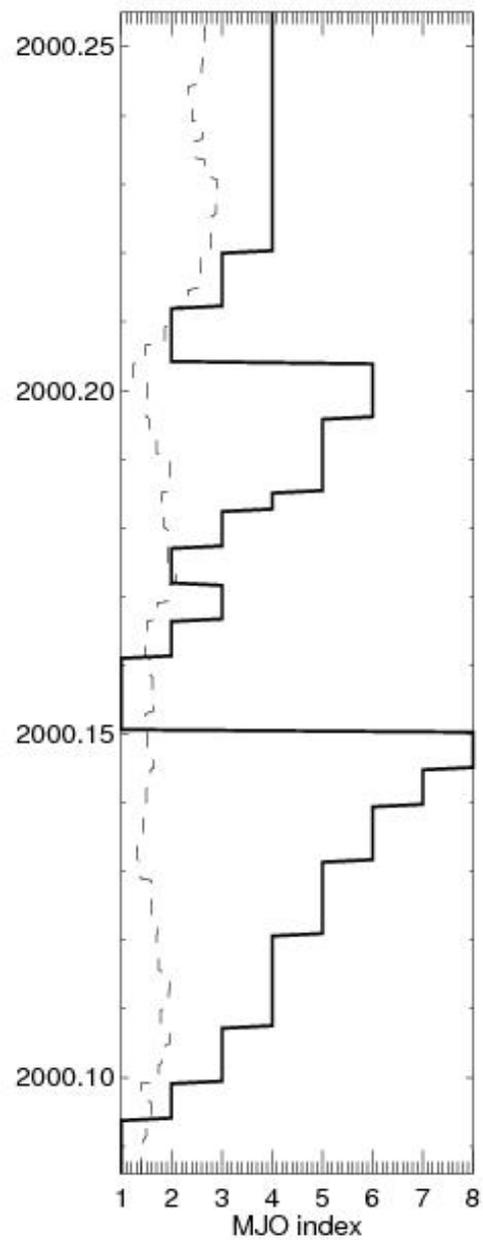
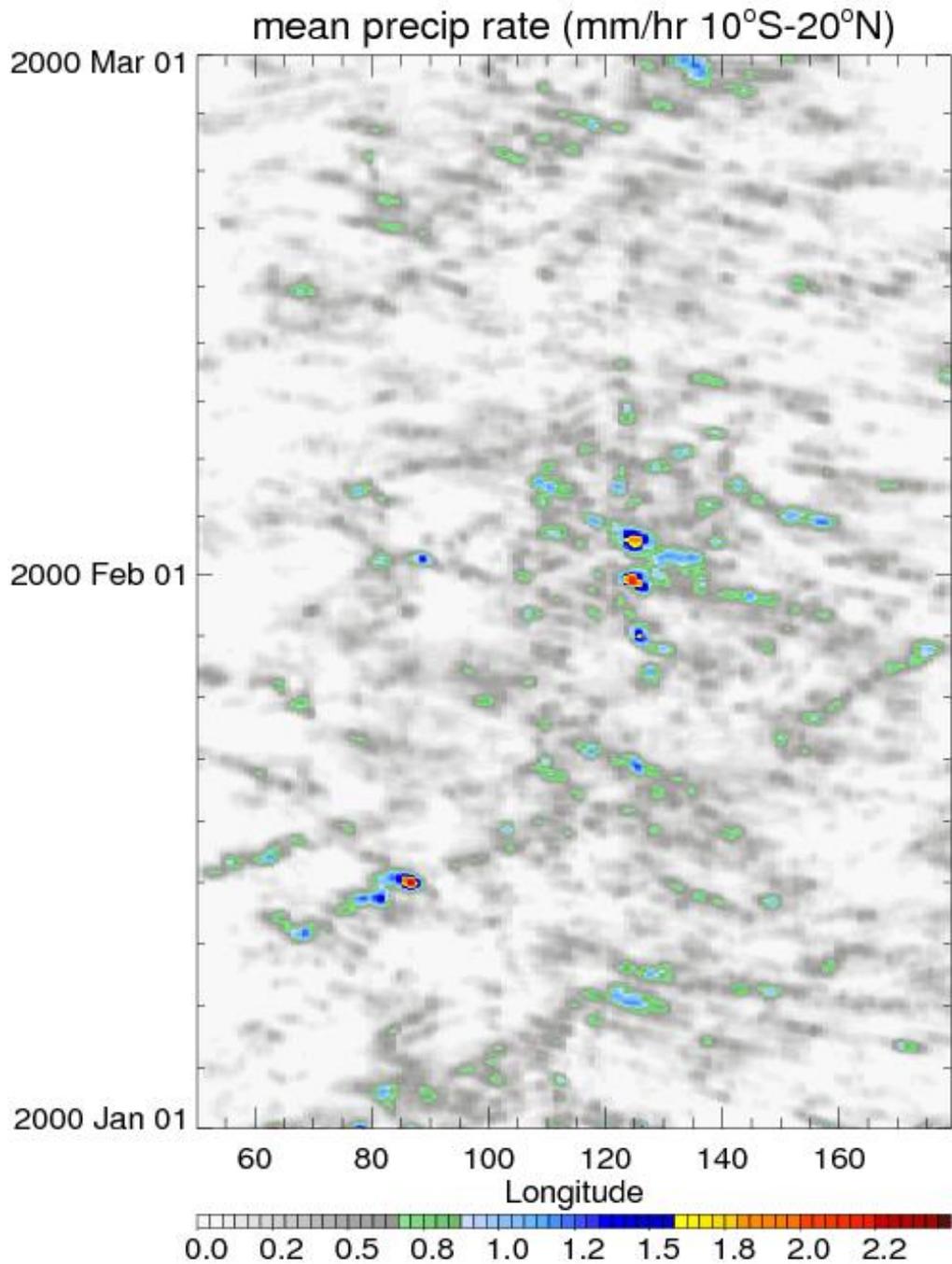
Precipitation depth vs. Local time (2D histogram)

Precip
depth

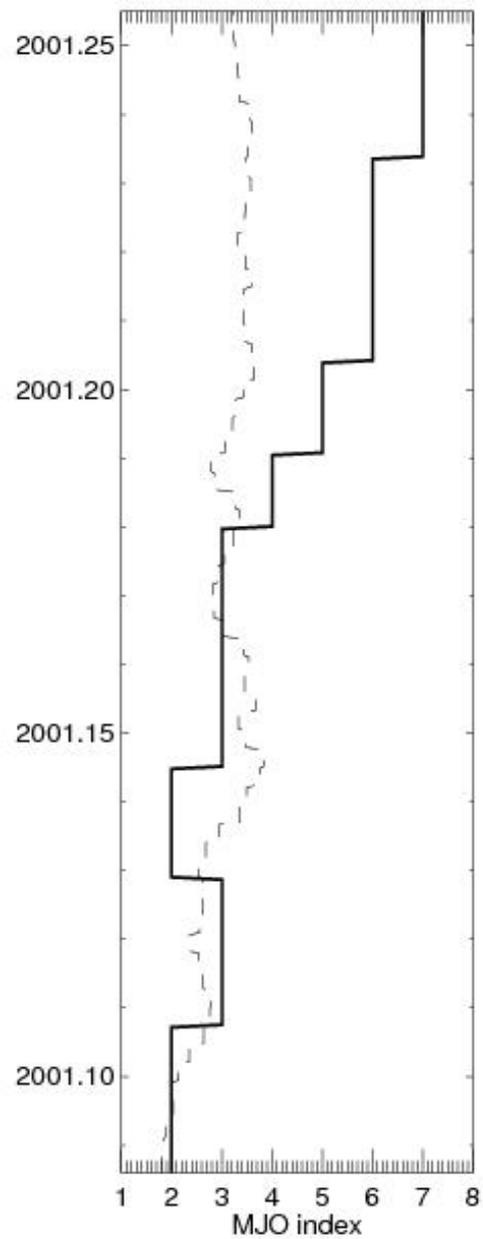
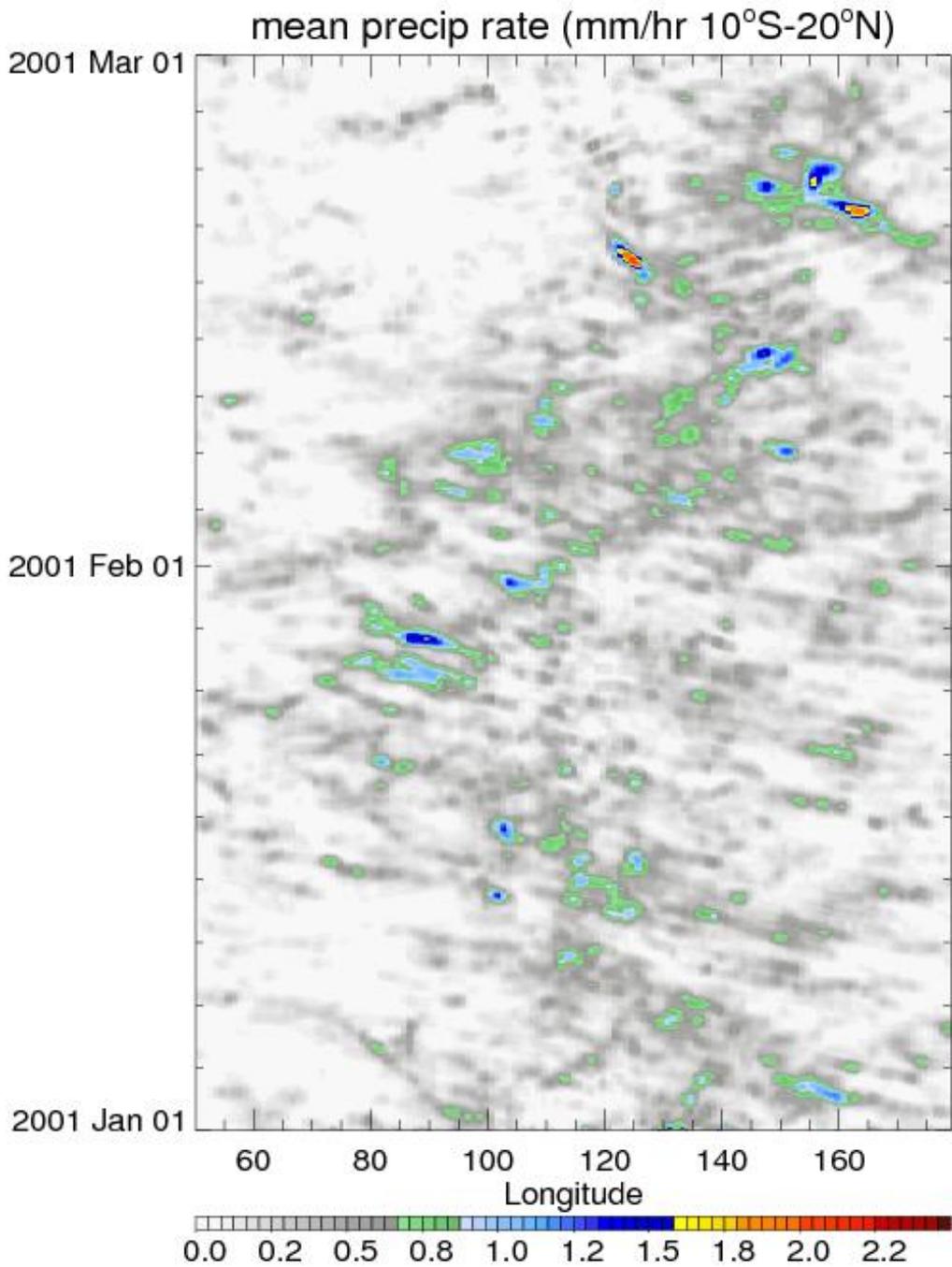


No much variation in the depths of precipitation

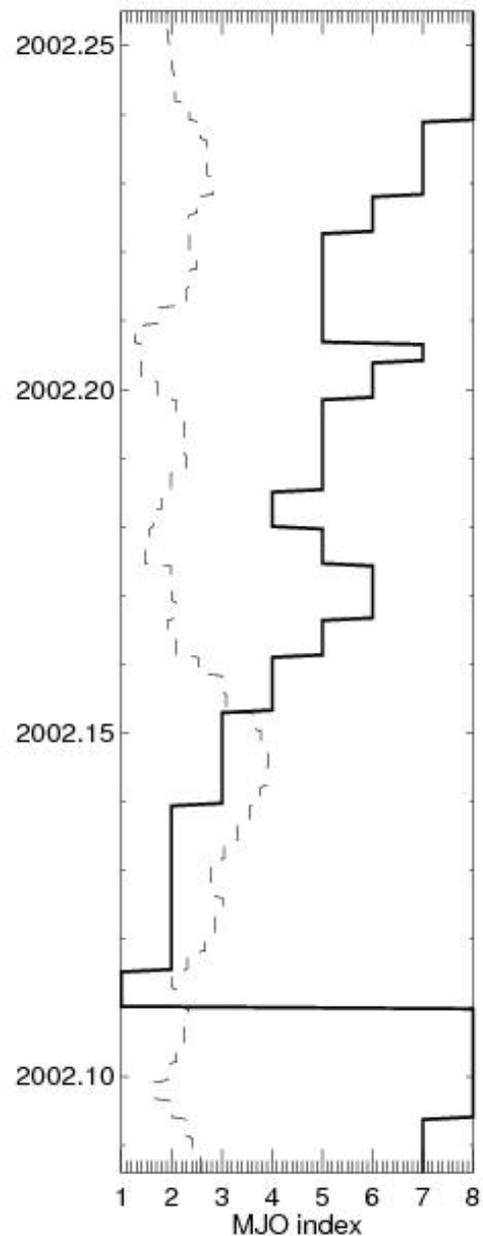
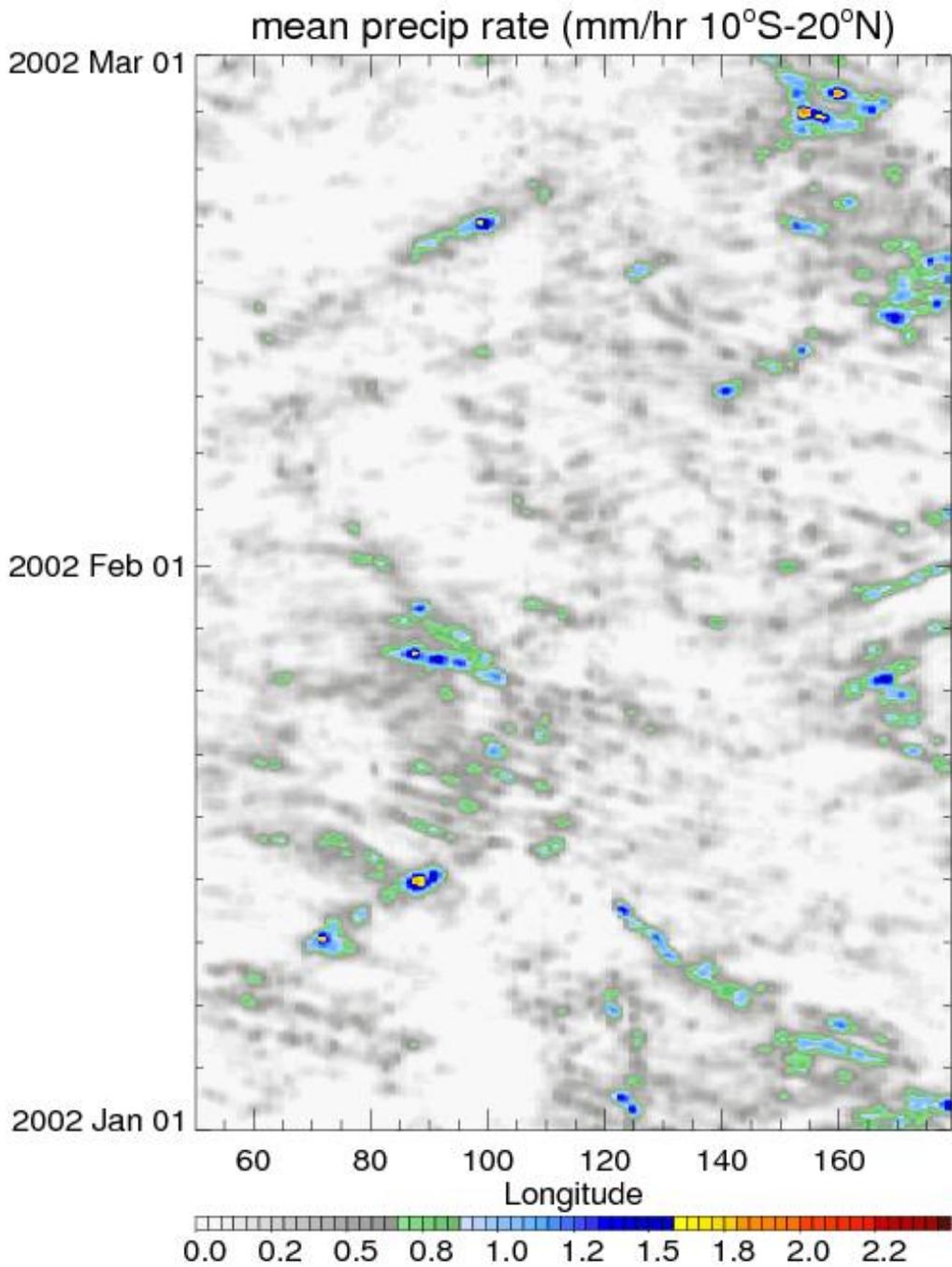
2000



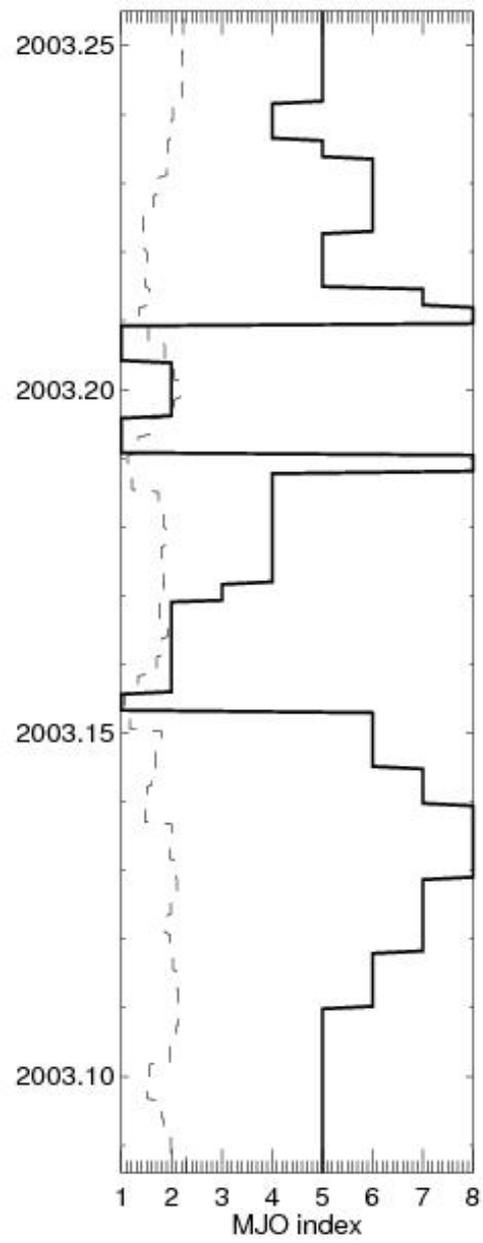
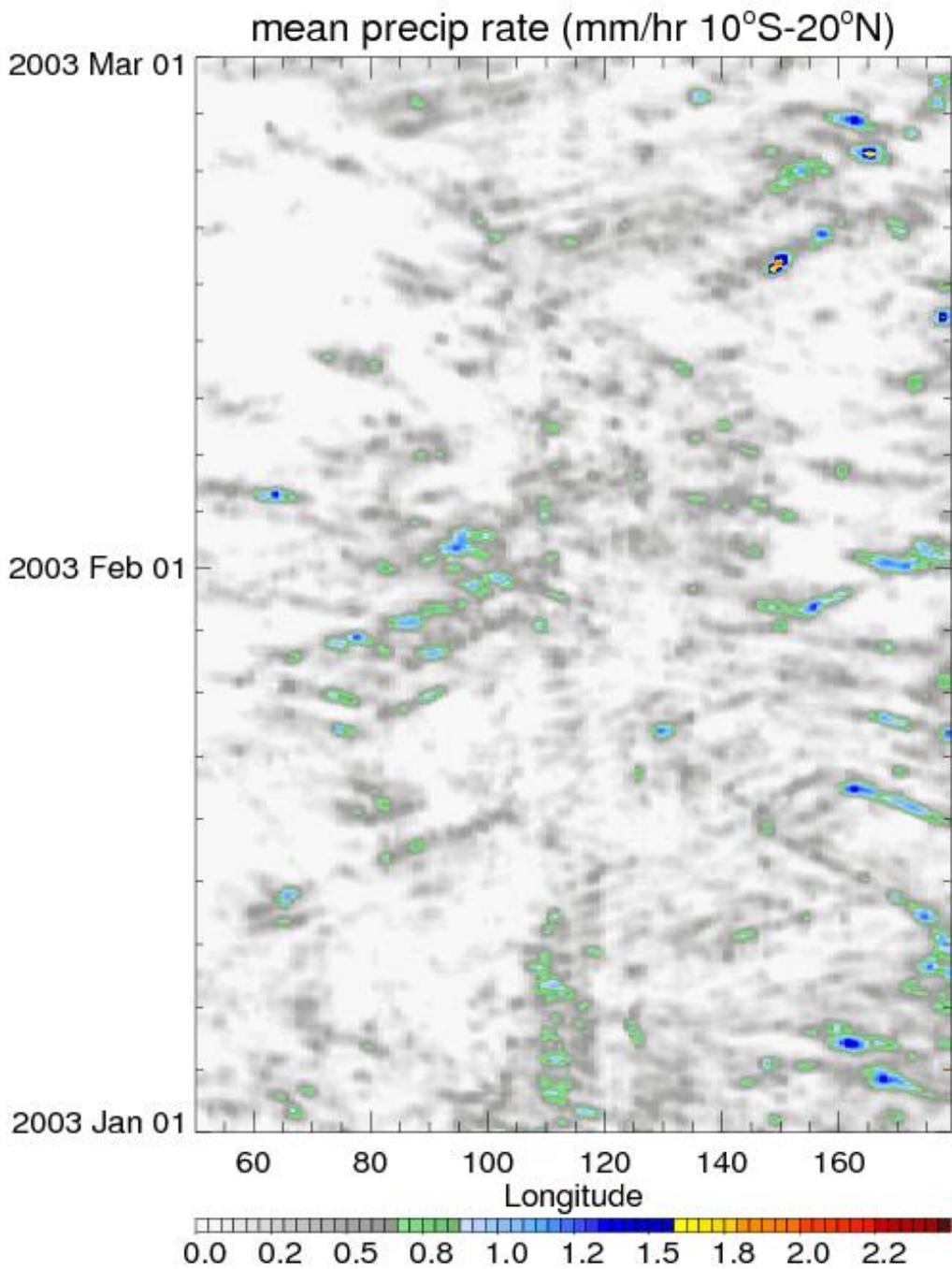
2001



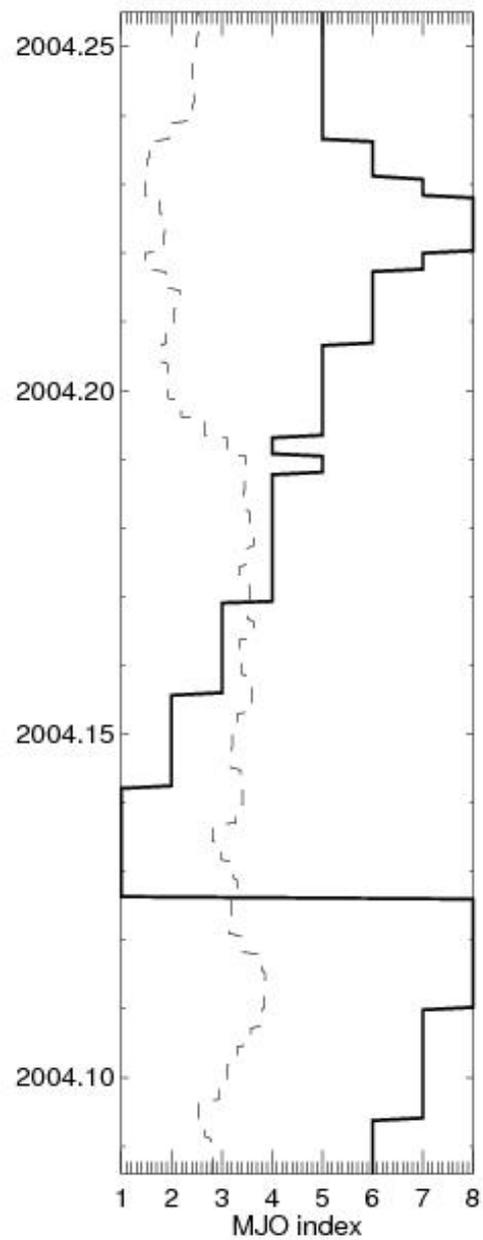
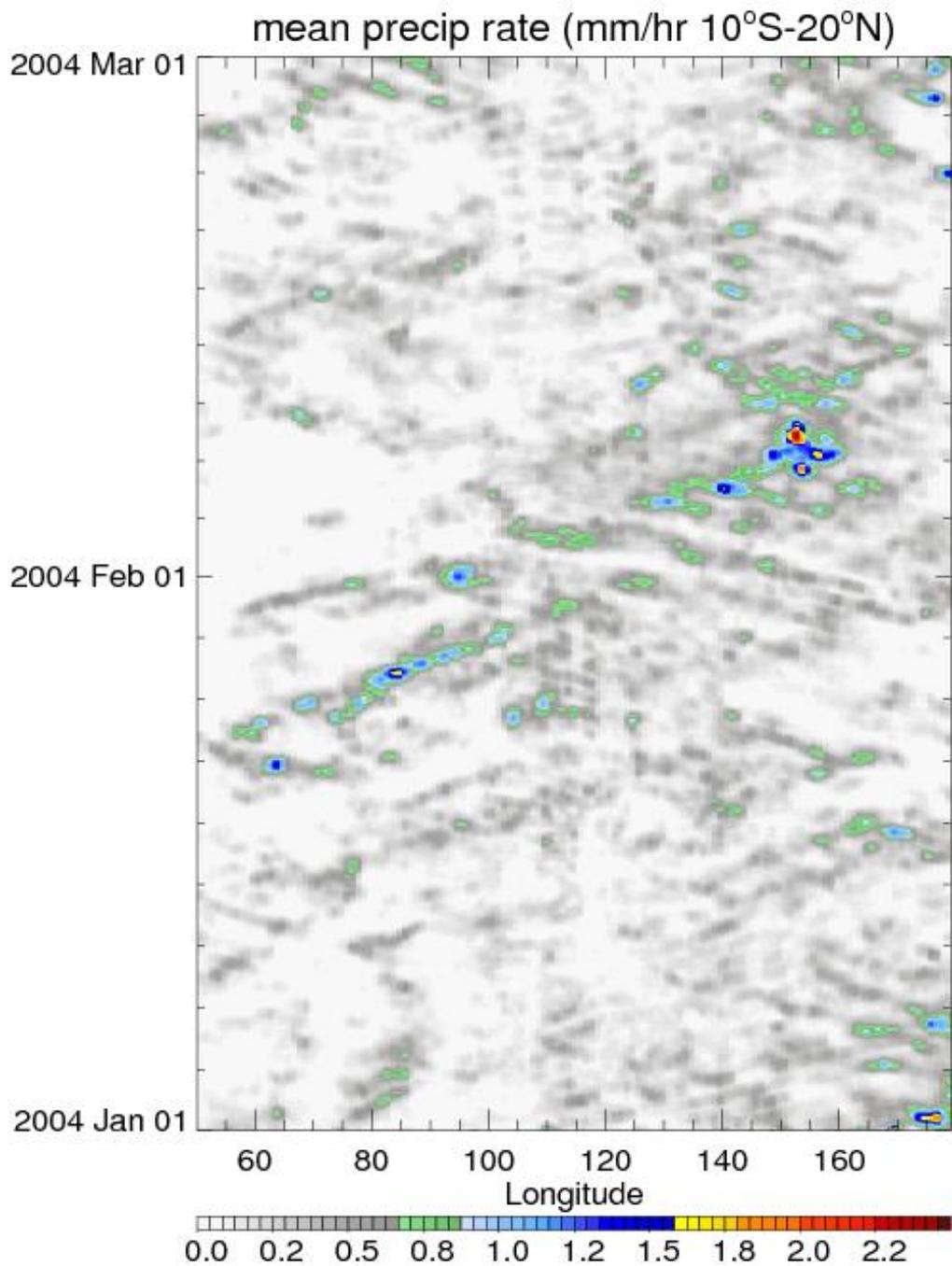
2002



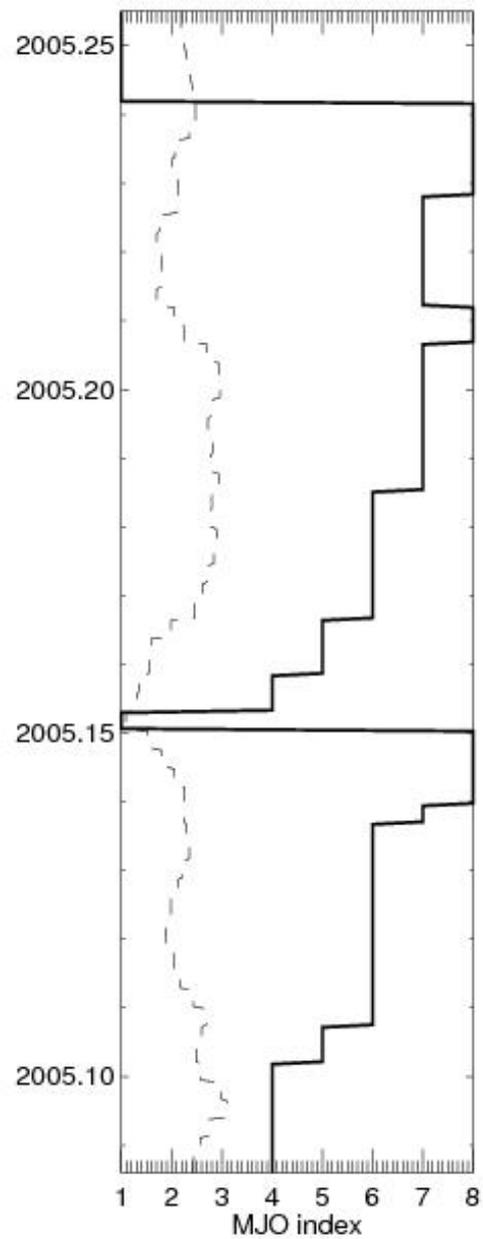
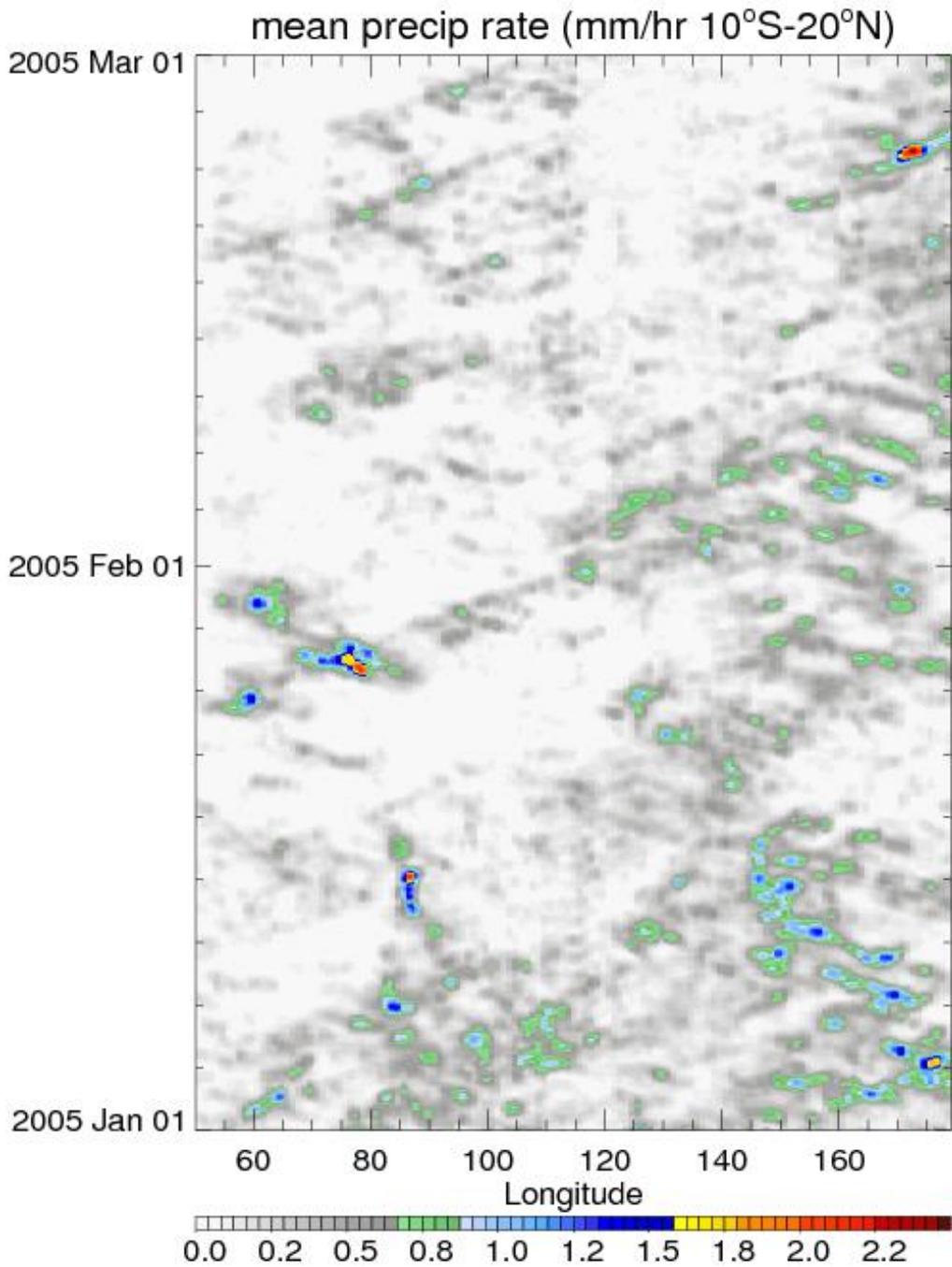
2003



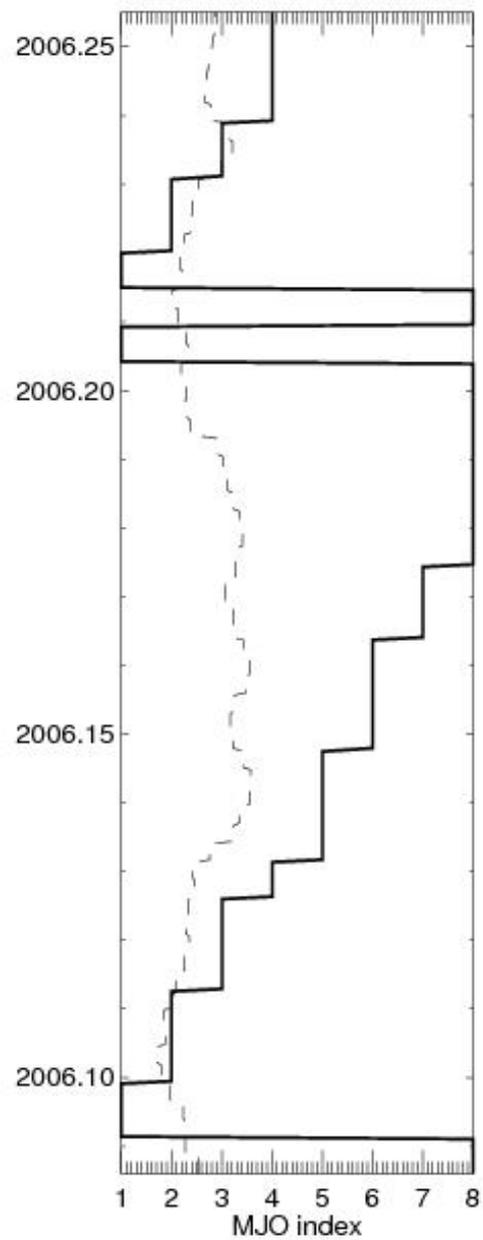
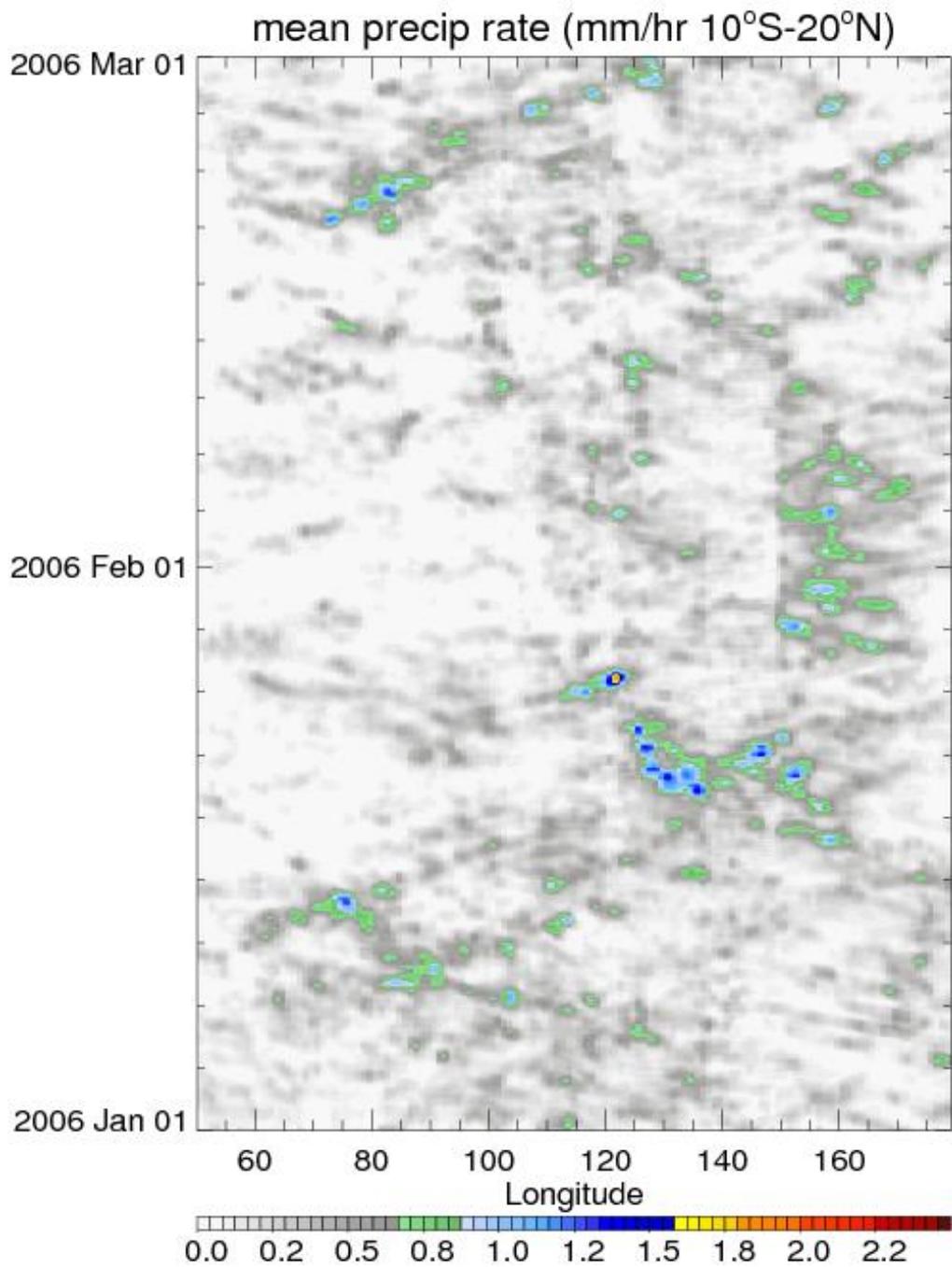
2004



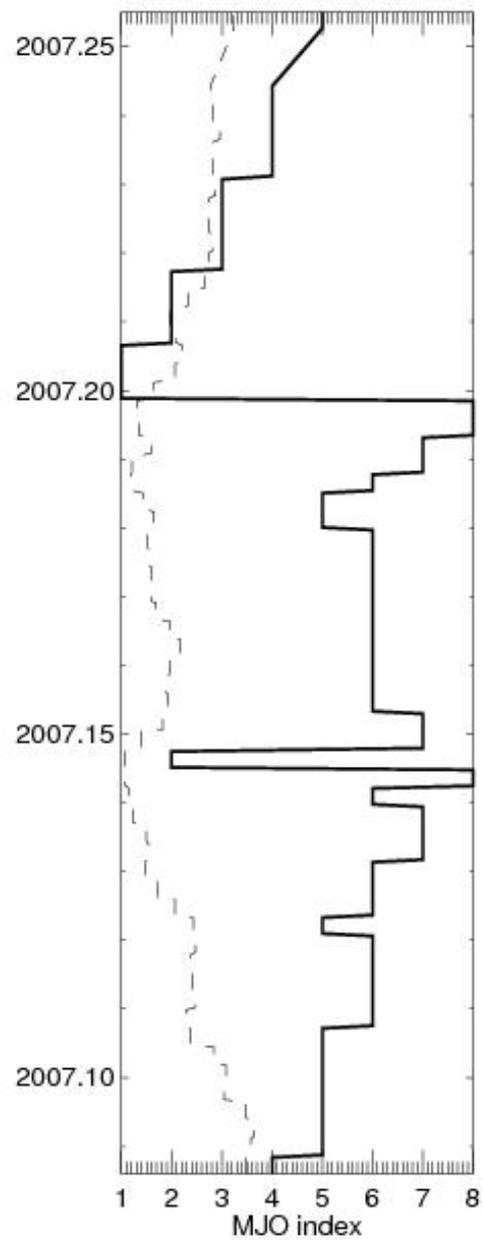
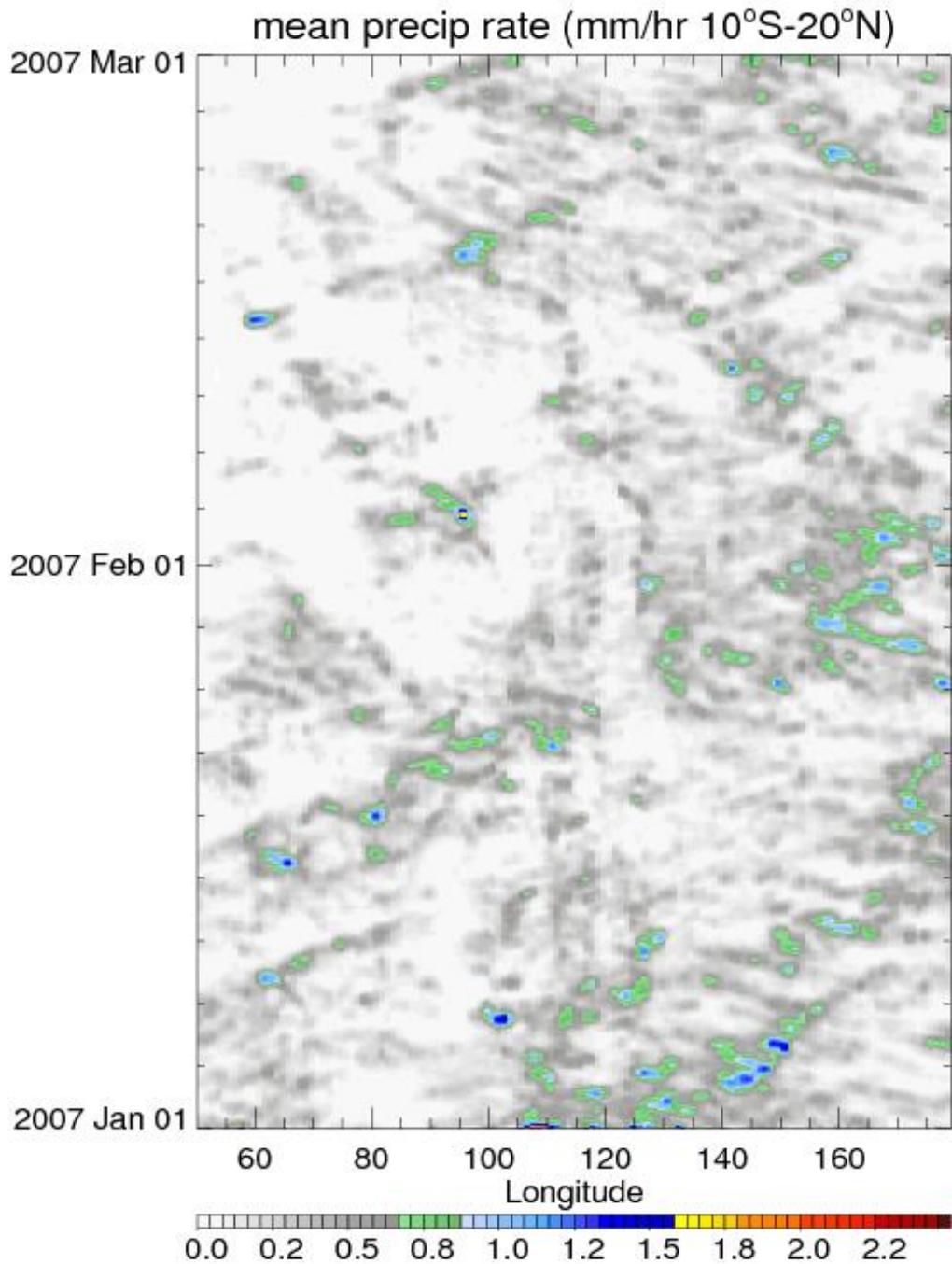
2005



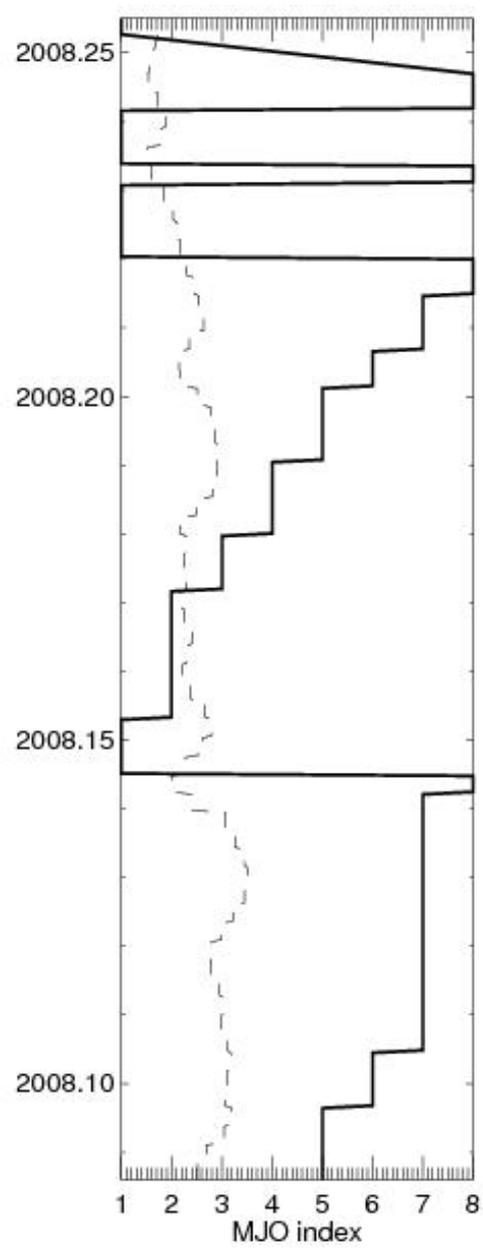
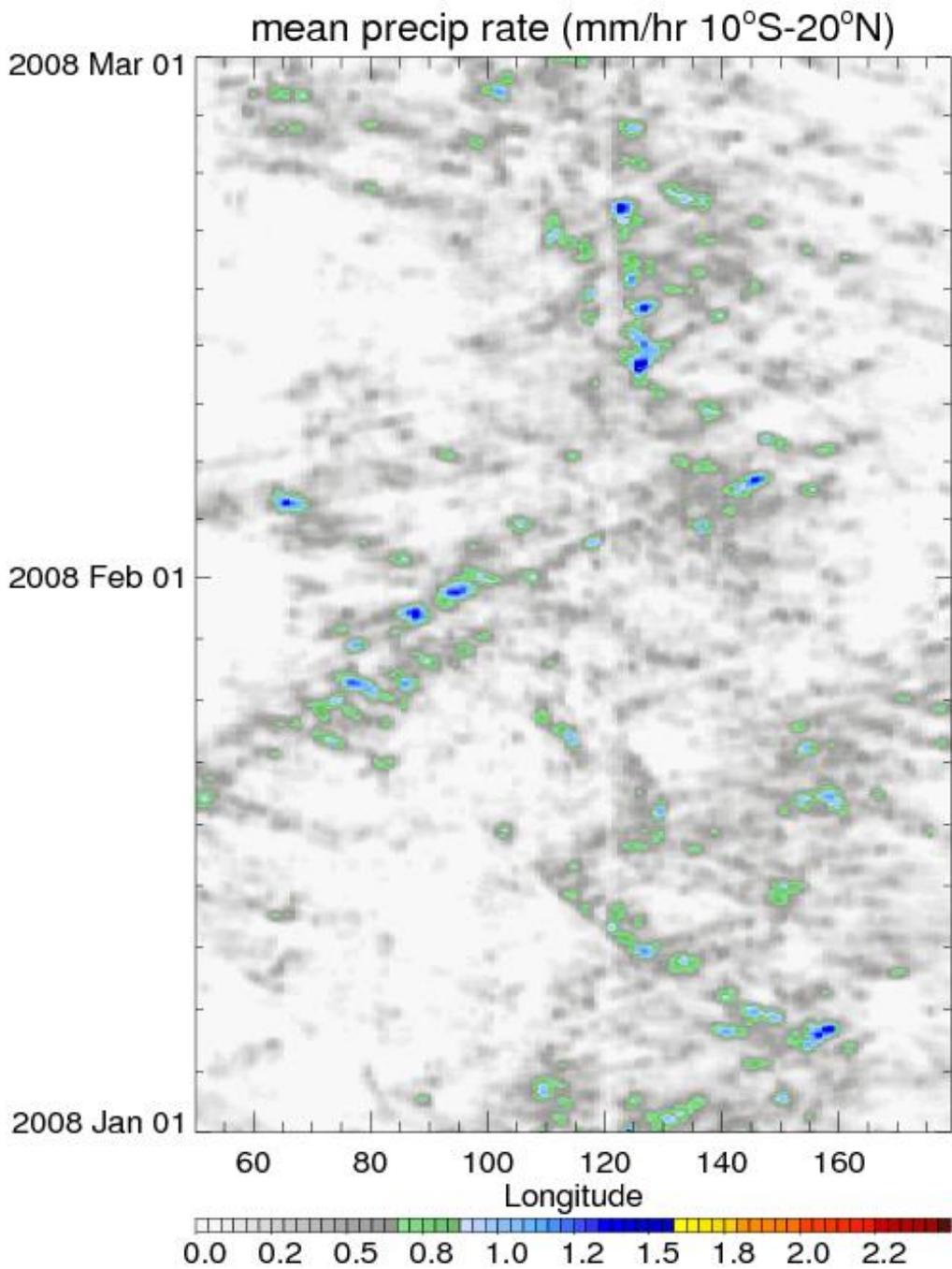
2006



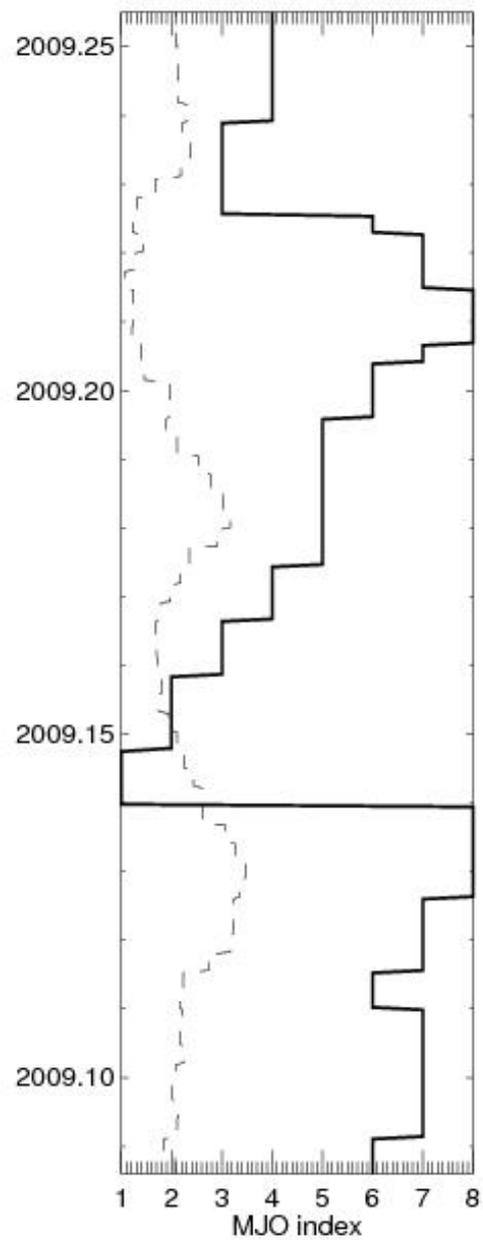
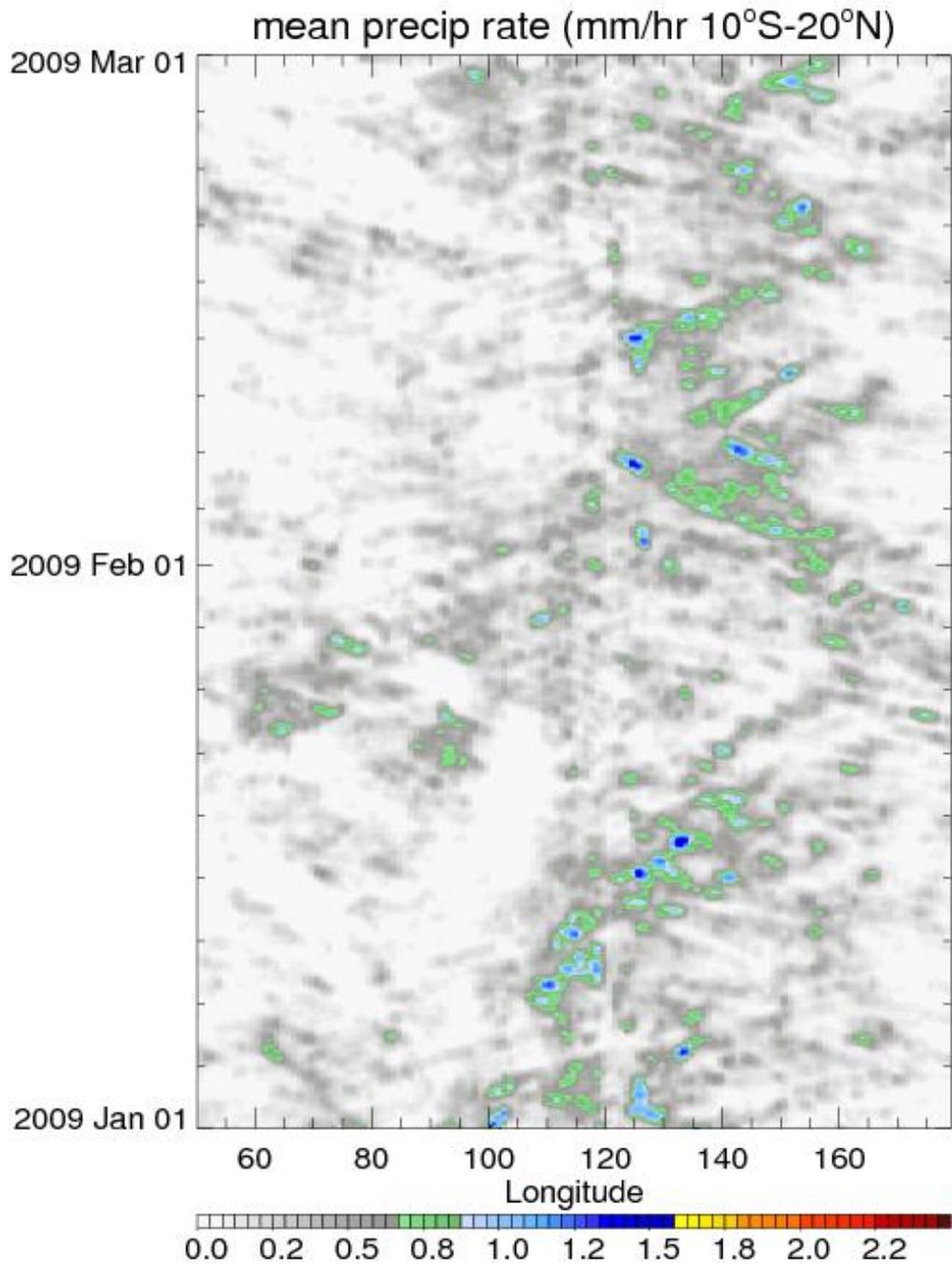
2007



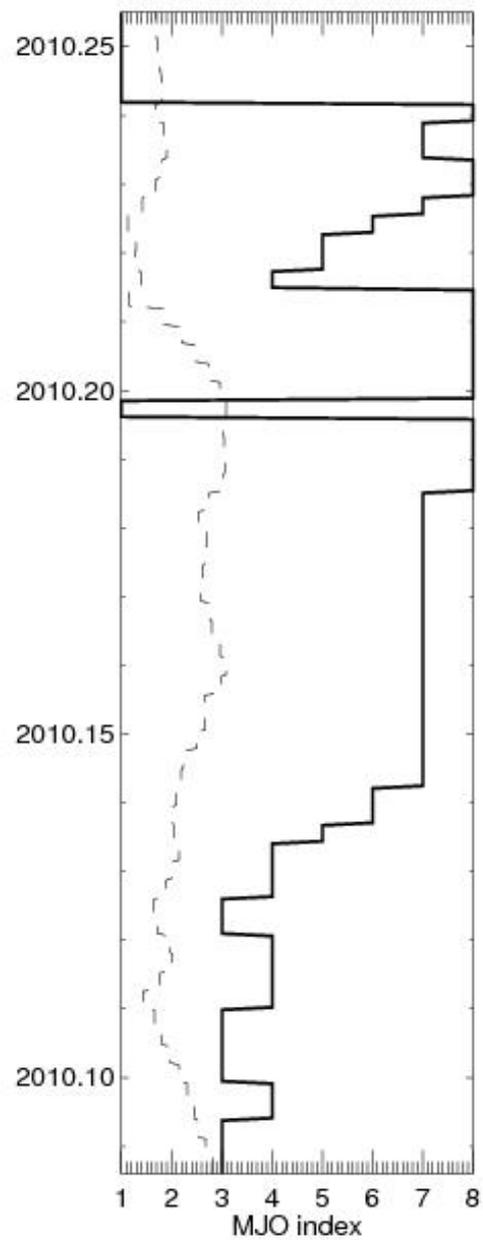
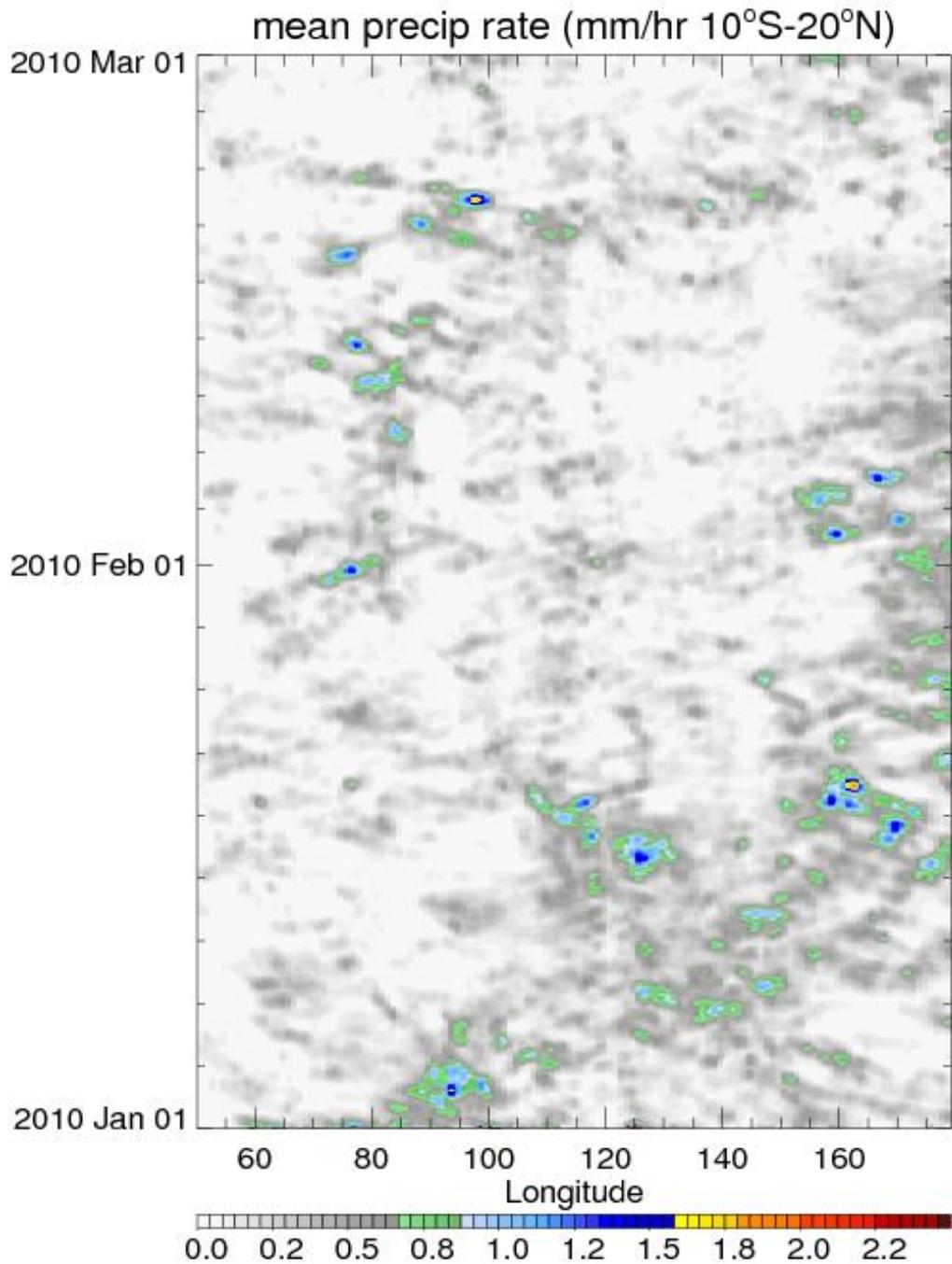
2008



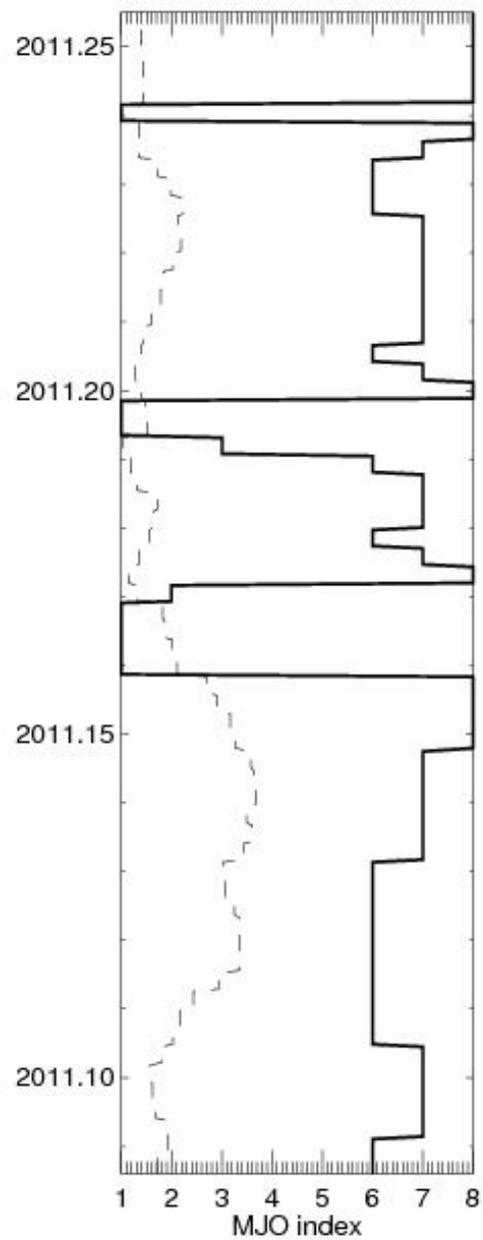
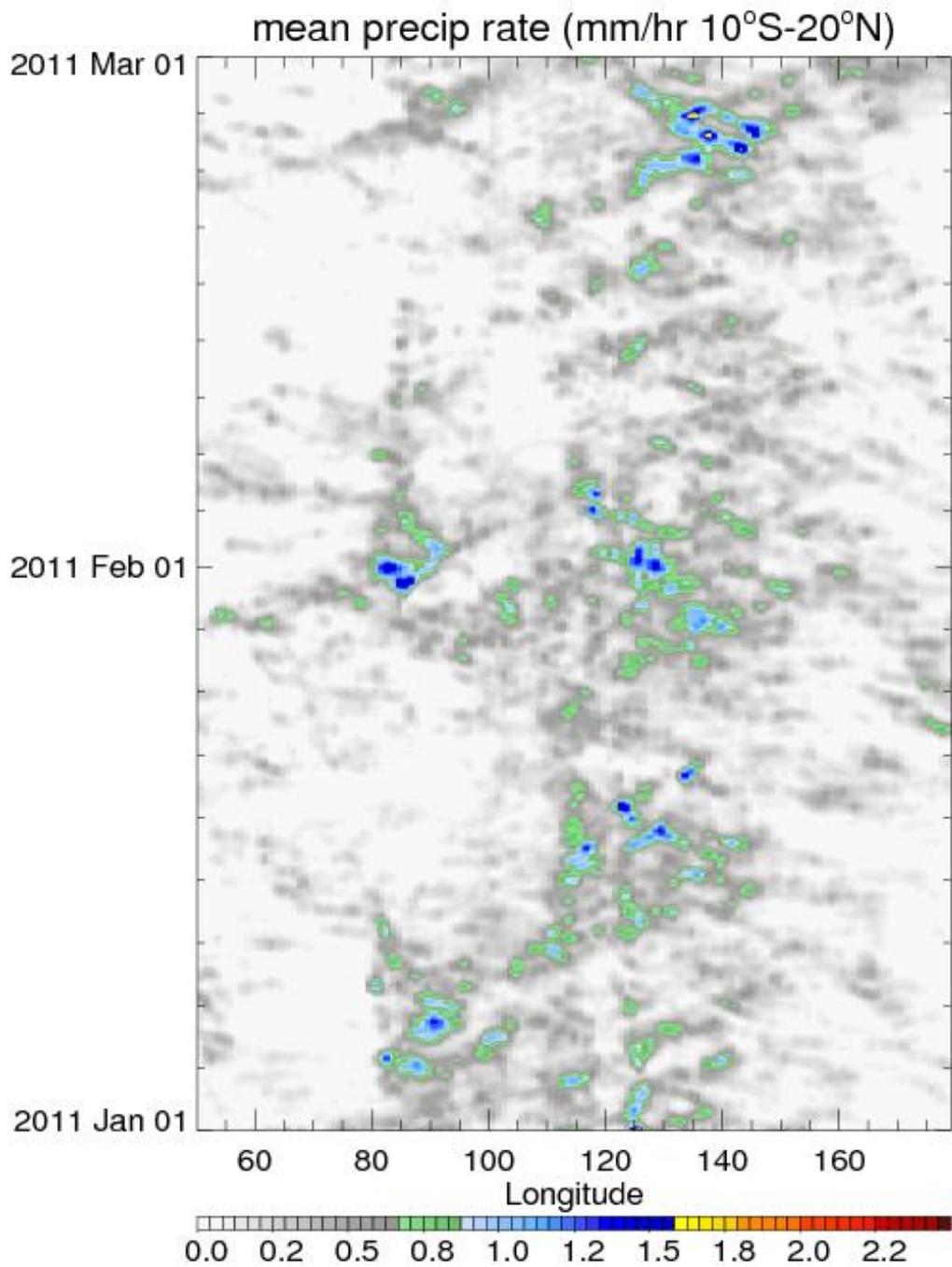
2009



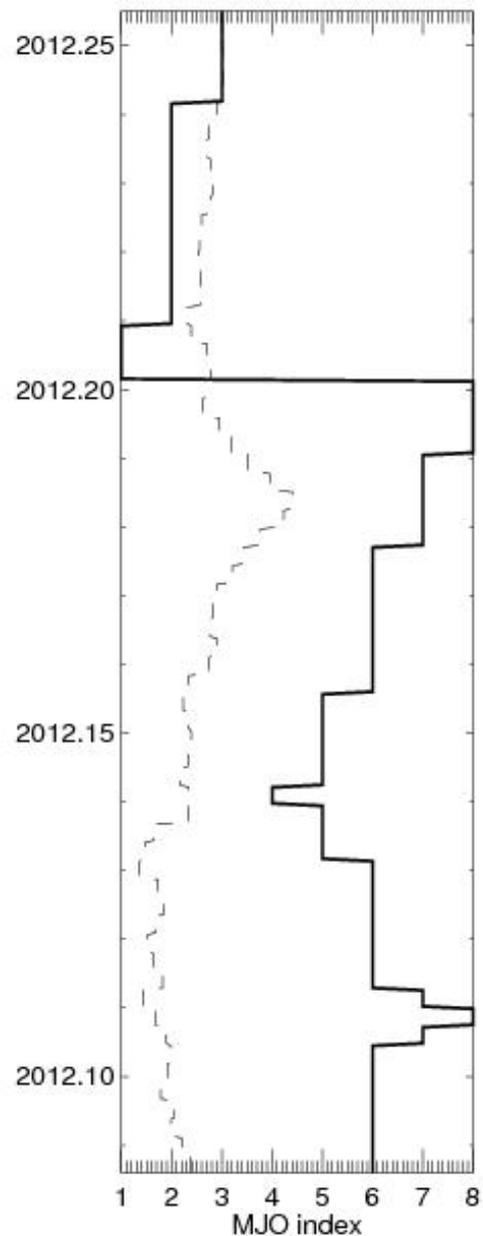
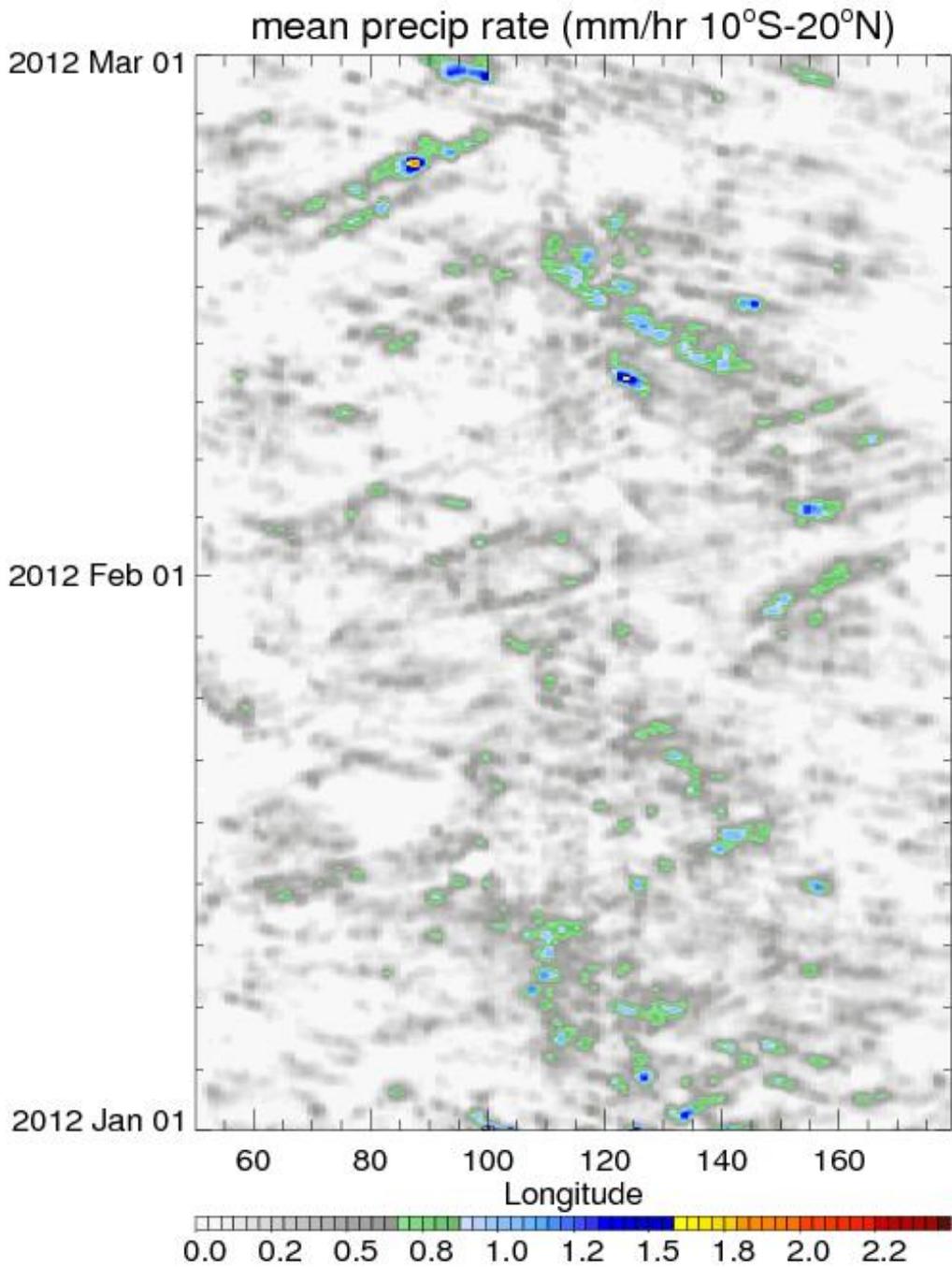
2010



2011



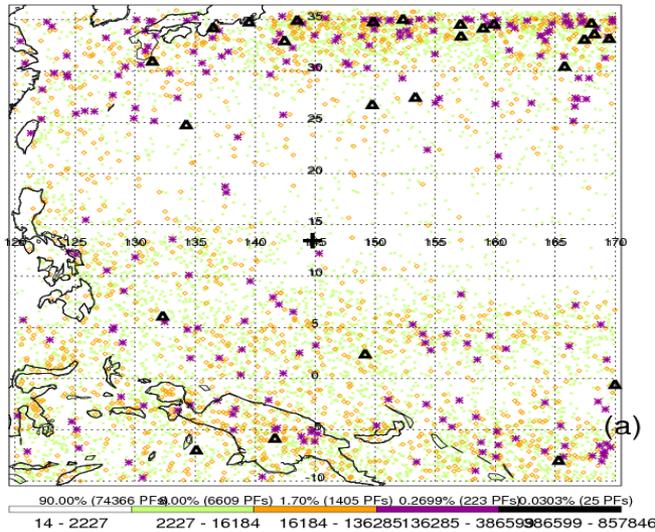
2012



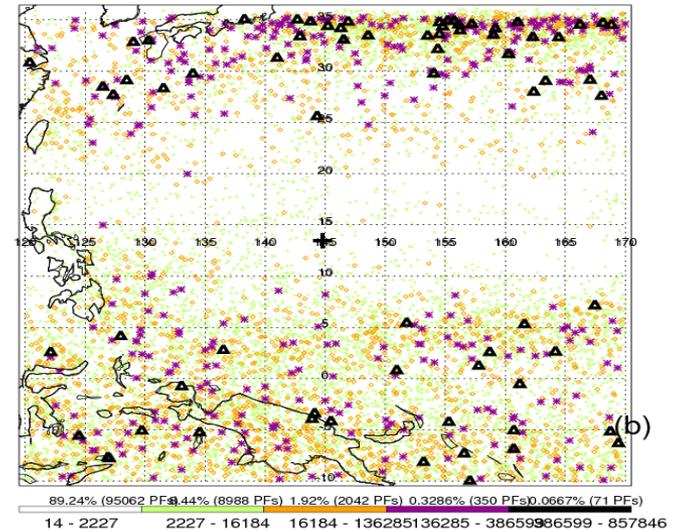
Precipitation systems categorized by rain volume

**MJO
1-2**

MJO Phase 1-2 locations of RPFs categorized by volumetric rainfall (mm/hr*km²)



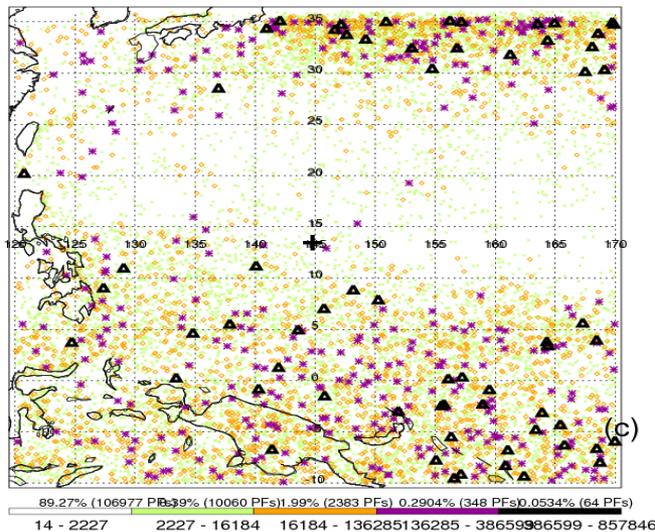
MJO Phase 3-4



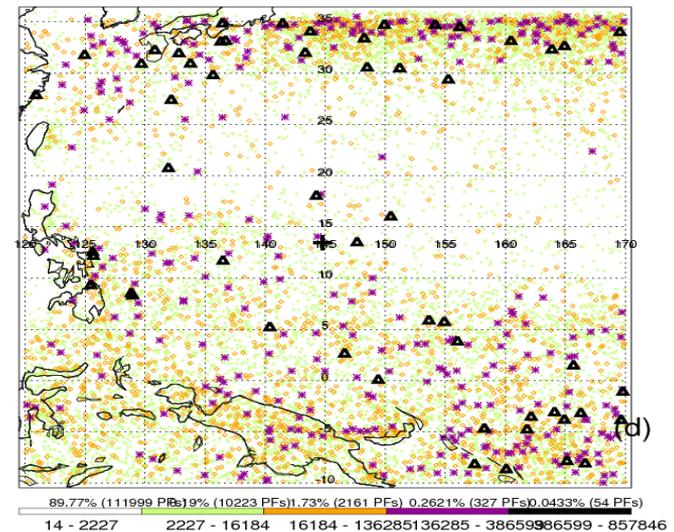
**MJO
3-4**

**MJO
5-6**

MJO Phase 5-6



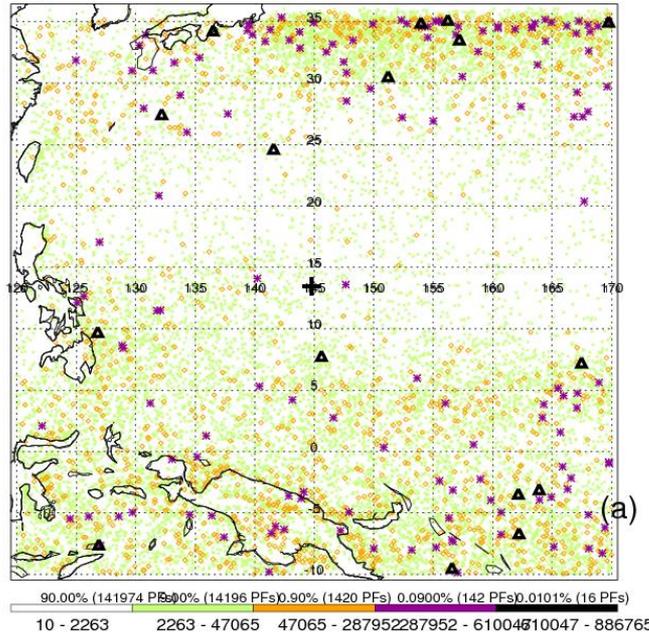
MJO Phase 7-8



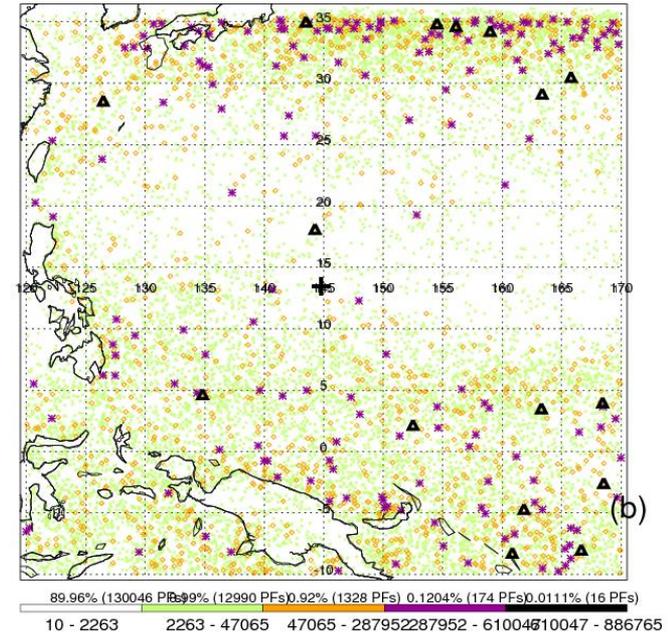
**MJO
7-8**

Rain volume

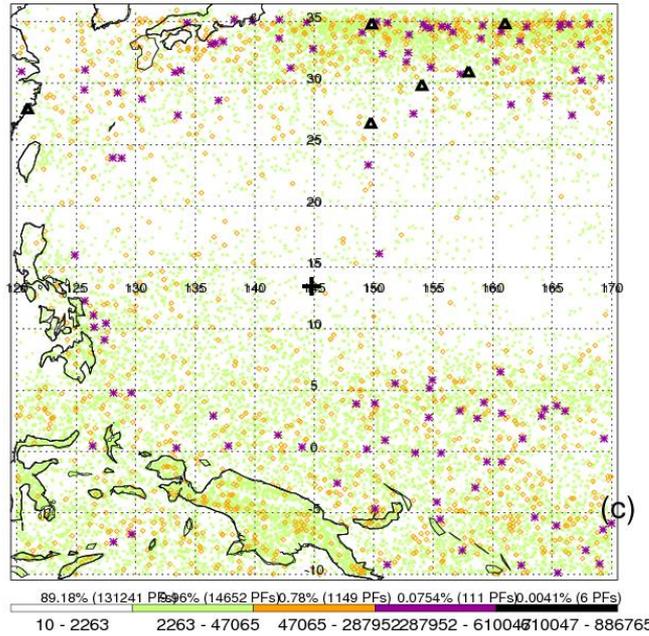
LT 00-06 locations of RPFs categorized by volumetric rainfall (mm/hr*km²)



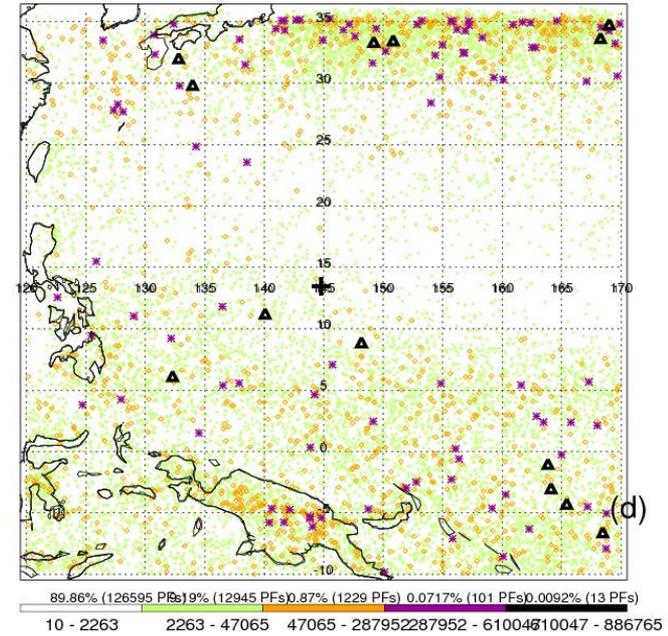
LT 06-12



LT 12-18

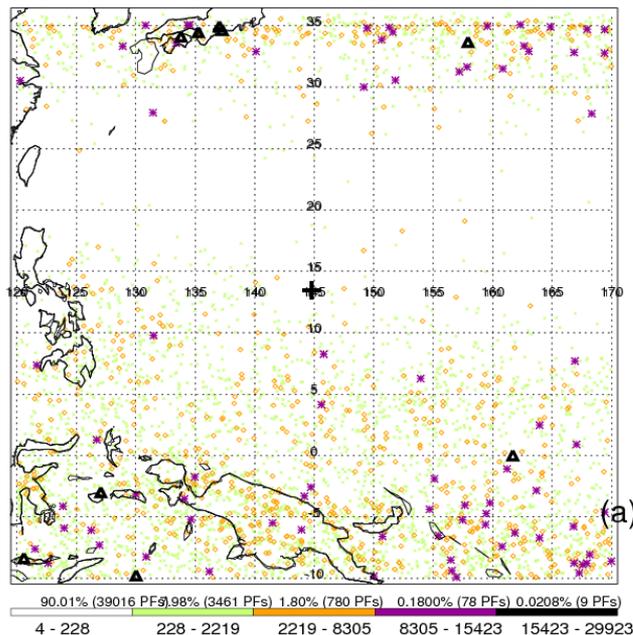


LT 18-24

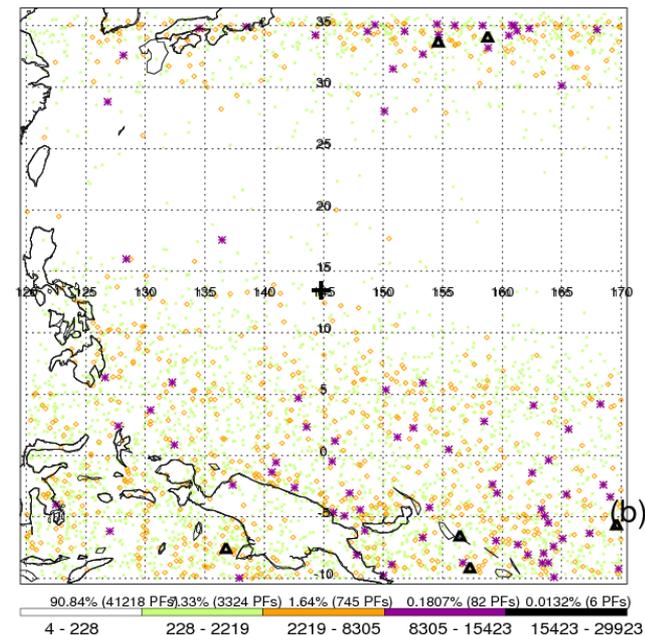


Cold cloud size

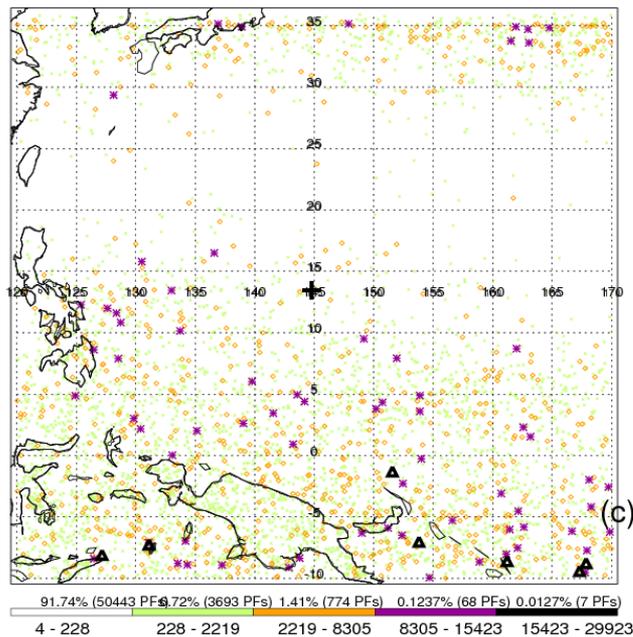
LT 00-06 locations of RPFs categorized by number of pixels with $T_{B_{11}} < 235$ K (#)



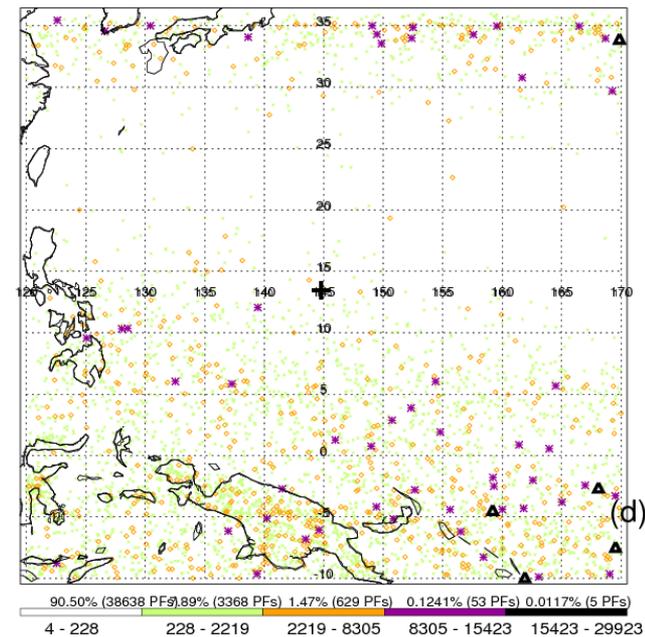
LT 06-12



LT 12-18

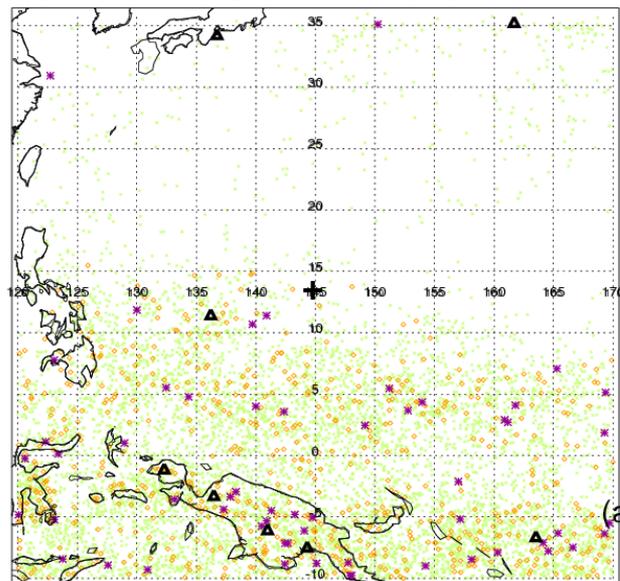


LT 18-24



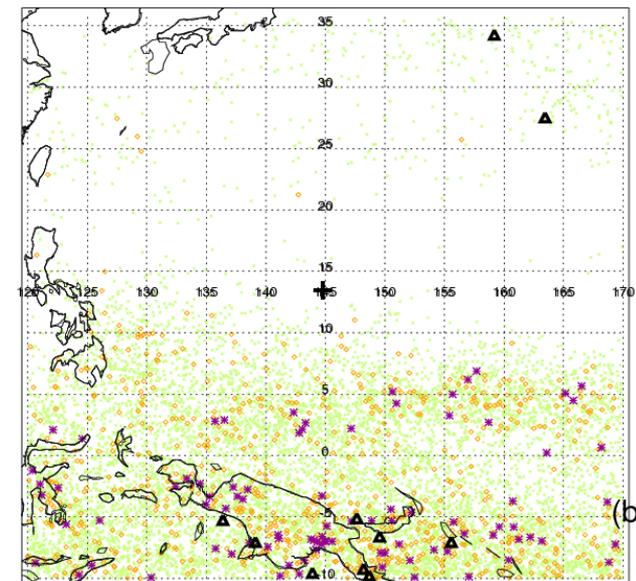
Depth

MJO Phase 1-2 locations of RPFs categorized by maximum height of 20 dBZ (km)



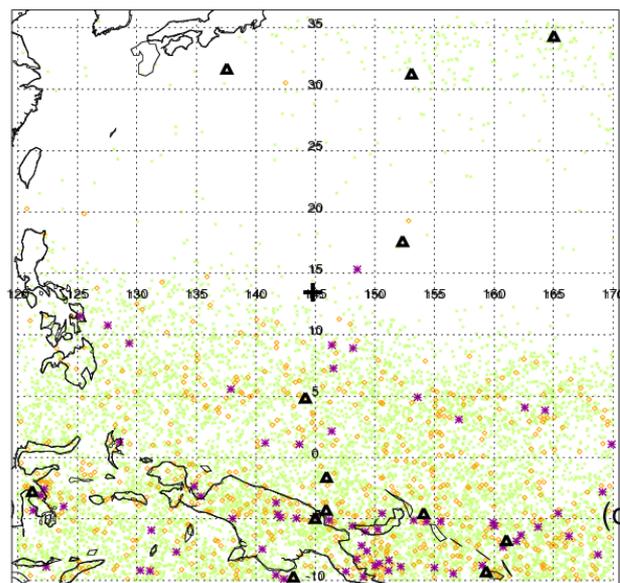
90.64% (74896 PFs) 4.47% (6995 PFs) 0.81% (672 PFs) 0.0690% (57 PFs) 0.0097% (8 PFs)
0.00 - 7.25 7.25 - 13.25 13.25 - 16.00 16.00 - 17.25 17.25 - 19.75

MJO Phase 3-4



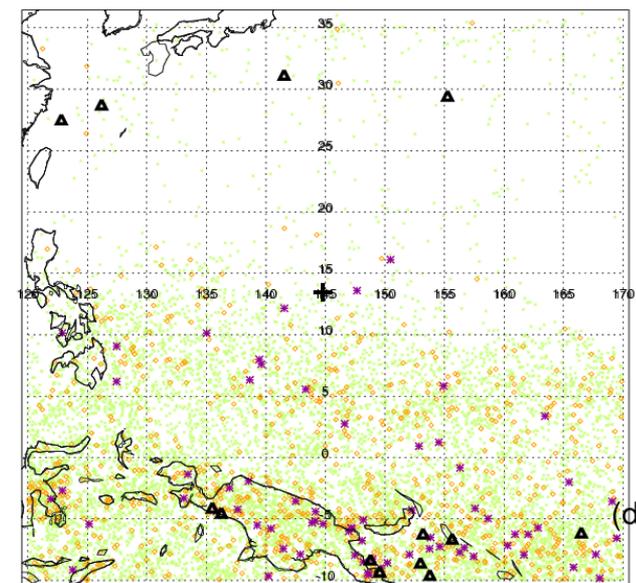
90.69% (96607 PFs) 4.50% (9058 PFs) 0.71% (756 PFs) 0.0836% (89 PFs) 0.0094% (10 PFs)
0.00 - 7.25 7.25 - 13.25 13.25 - 16.00 16.00 - 17.25 17.25 - 19.75

MJO Phase 5-6



92.06% (110317 PFs) 4.14% (8797 PFs) 0.53% (640 PFs) 0.0567% (68 PFs) 0.0108% (13 PFs)
0.00 - 7.25 7.25 - 13.25 13.25 - 16.00 16.00 - 17.25 17.25 - 19.75

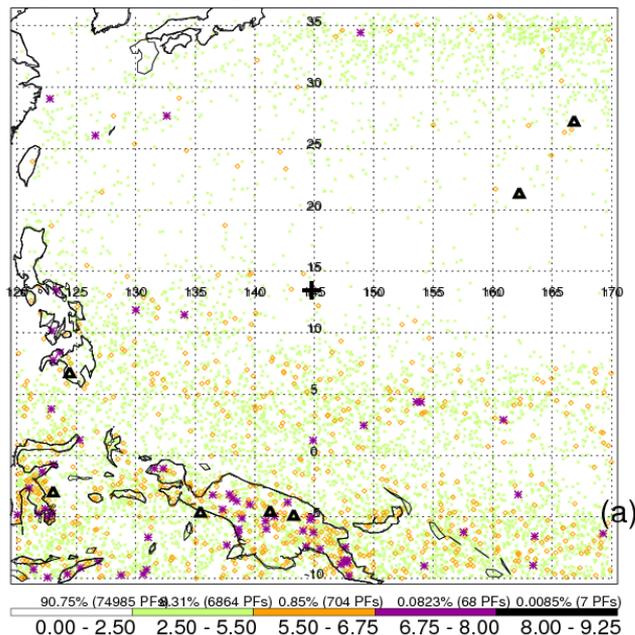
MJO Phase 7-8



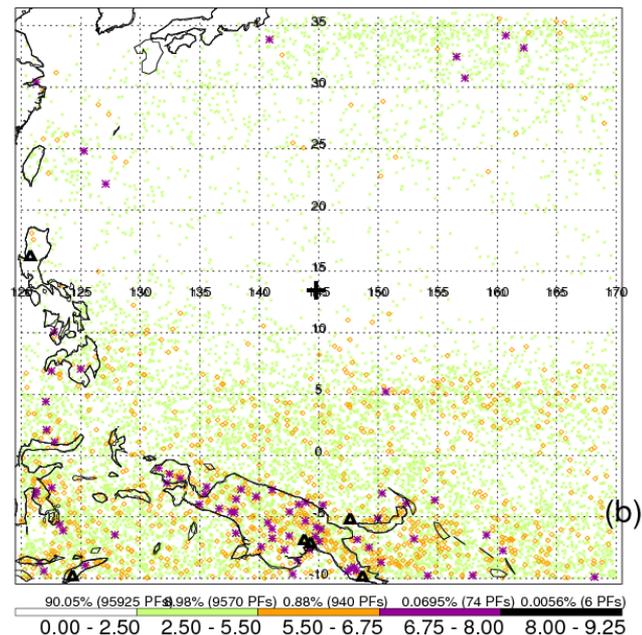
91.62% (114311 PFs) 4.33% (9521 PFs) 0.68% (850 PFs) 0.0561% (70 PFs) 0.0104% (13 PFs)
0.00 - 7.25 7.25 - 13.25 13.25 - 16.00 16.00 - 17.25 17.25 - 19.75

Convective intensity

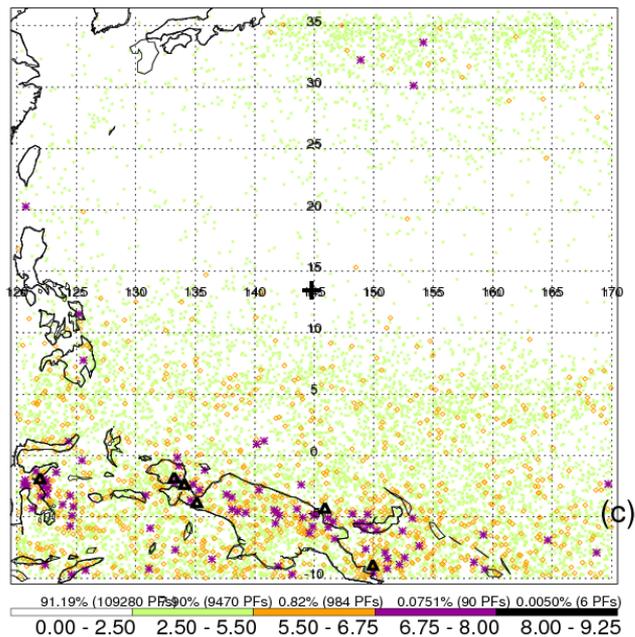
MJO Phase 1-2 locations of RPFs categorized by maximum height of 40 dBZ (km)



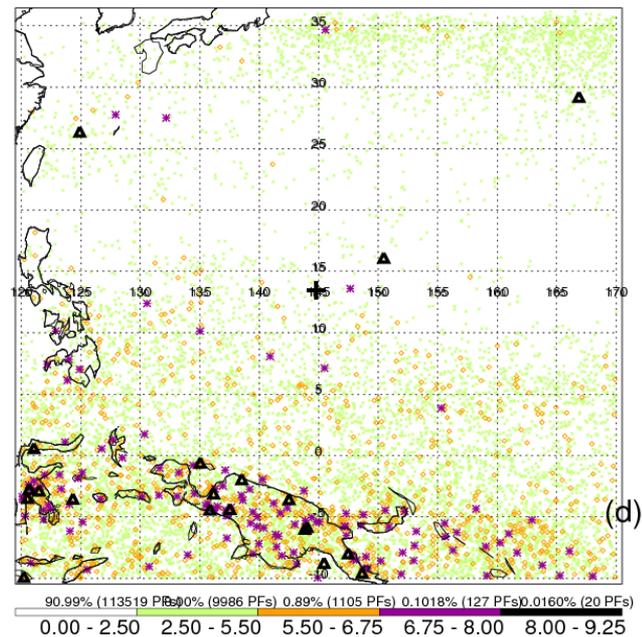
MJO Phase 3-4



MJO Phase 5-6

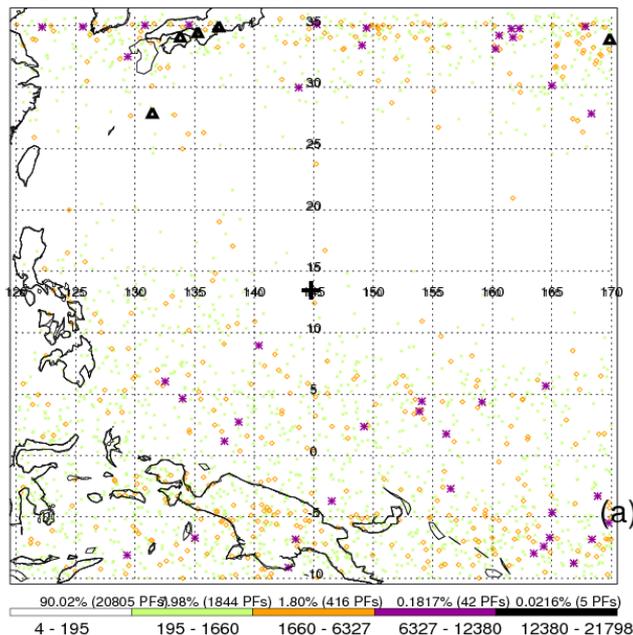


MJO Phase 7-8

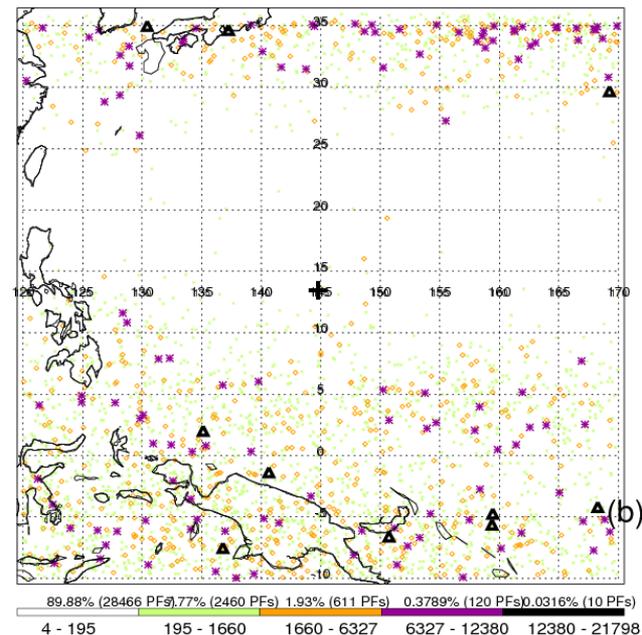


Cold cloud area

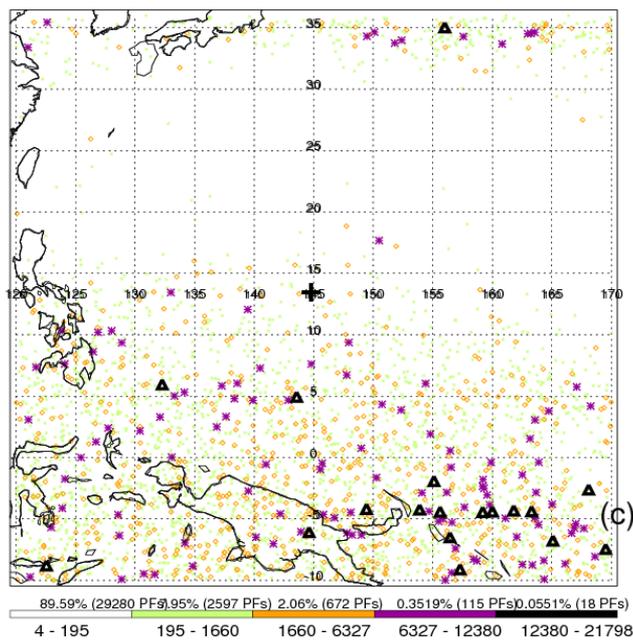
MJO Phase 1-2 locations of RPFs categorized by # pixels with $T_{B11} < 235$ K



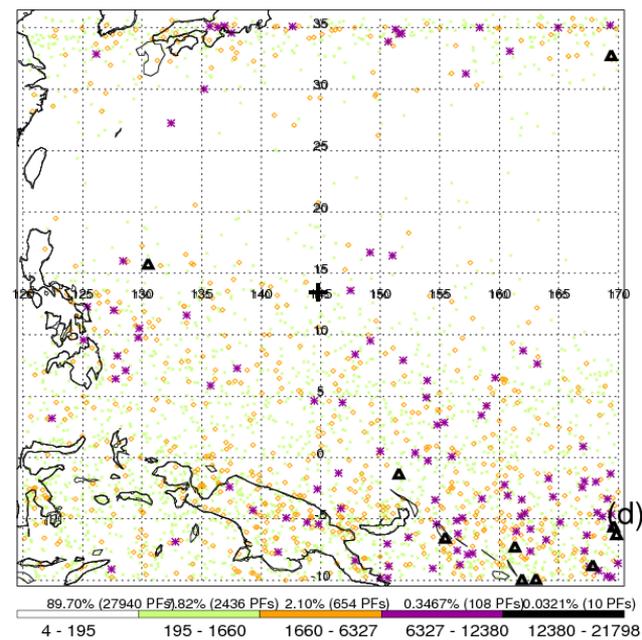
MJO Phase 3-4



MJO Phase 5-6



MJO Phase 7-8



**Cloud
Size**

