Precipitation Characteristics in Coastal Area of Alaska Revealed from Spaceborne Radars

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1. Introduction

The coastal area receives relatively large amount of precipitation. Climatological precipitation dataset from TRMM PR has revealed that the concentrated precipitation in the tropical coastal regions plays an important role in the global water circulation between ocean and land (Fig. 1; Ogino et al. 2017). We used a newly obtained dataset from GPM DPR to investigate the precipitation in mid-high latitude, where TRMM PR does not cover. In mid-high latitude, precipitation concentrates especially on the west coast of the continent (such place as Alaska, Patagonia, Norway, Greenland and New Zealand), thus we focused on these area.

Our goal of this study is to reveal spatial patterns of precipitation climatology and precipitation mechanism in coastal area of mid-high latitude by using two spaceborne radars, GPM DPR(KuPR) and CloudSat CPR.

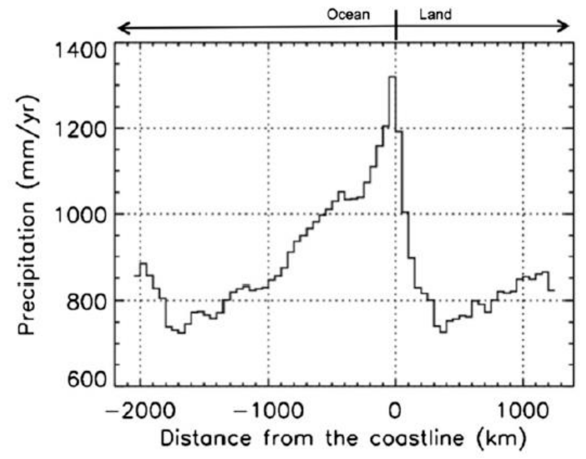


Figure 1. Relationship between precipitation amount and distance from the coastline in tropics derived from TRMM PR 3A25. (Ogino et al. 2016)

2. Data

We mainly focused on the south-western coast of Alaska because of the number of sampling. We resampled precipitation data from DPR and CPR (Table 1) into 0.1° × 0.1° grid boxes (45-65N, 125-155W), and calculated mean precipitation frequency and rate as a function of the distance from the nearest coastline, following Ogino et al. (2016).

Table 1. Spaceborne radar data resampled into grids in this study.

GPM DPR(Dual Frequency Radar)	Period: Apr 2014 - Mar 2019
Precipitation flag & rate	KuPR V06A LEVEL2
Z factor corrected	KuPR V06A LEVEL2
CloudSat CPR(Cloud Profiling Radar)	Period: Jul 2006 - Dec 2015
Precipitation flag (rain/mix/snow)	2C-PRECIP-COLUMN
Snowfall flag & rate	2C-SNOW-PROFILE
Cloud scenario (shallow/nimbo/other)	2B-CLDCLASS
Radar reflectivity	2B-GEOPROF

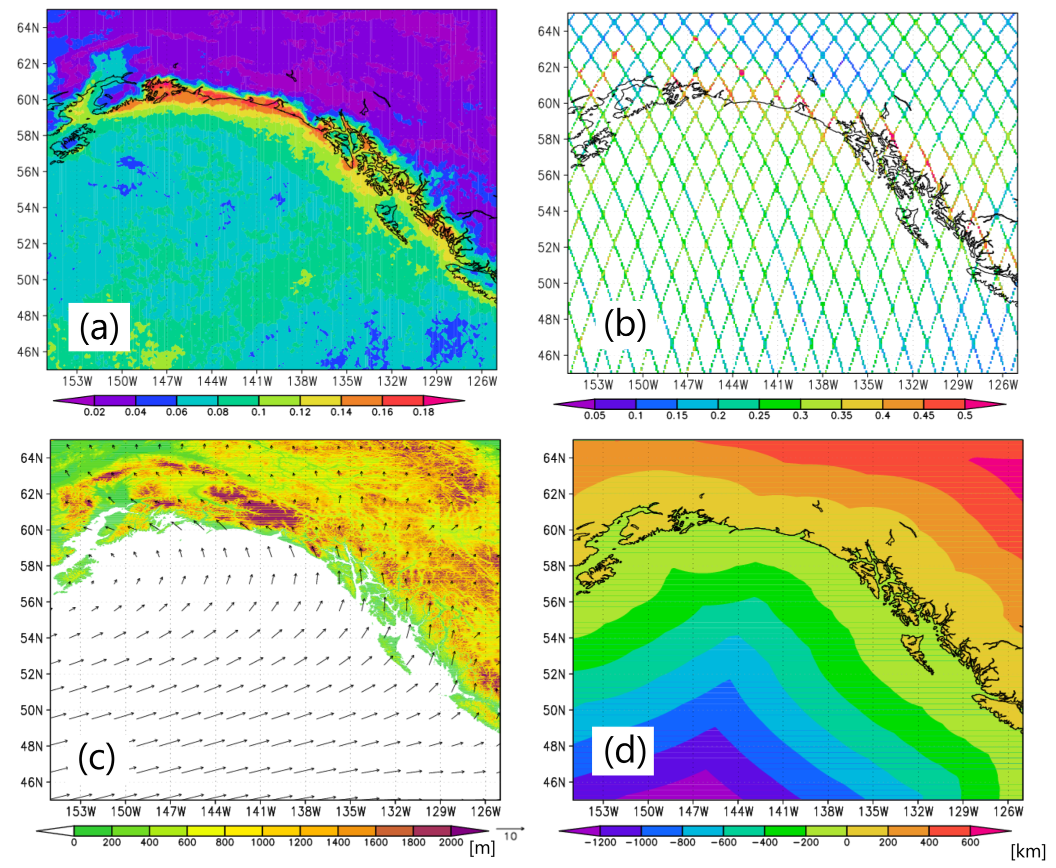


Figure 2. (a)GPM DPR(KuPR) precipitation frequency, (b)CloudSat CPR precipitation frequency, (c)elevation from SRTM30 and mean 850hPa horizontal wind vector from ERA-interim, (d)distance from the coastline around the Gulf of Alaska.

3. Precipitation around the Coastline

According to Fig. 3, precipitation events are frequently detected by DPR and relatively large amount of precipitation is brought above the coastal water. On the other hand, precipitation events are rarely detected by KuPR on the coastal mountains, where snowfall events are frequently detected by CPR. This may be because echo detected on land tend to be weaker than on the coastal water (Fig. 5a,b).

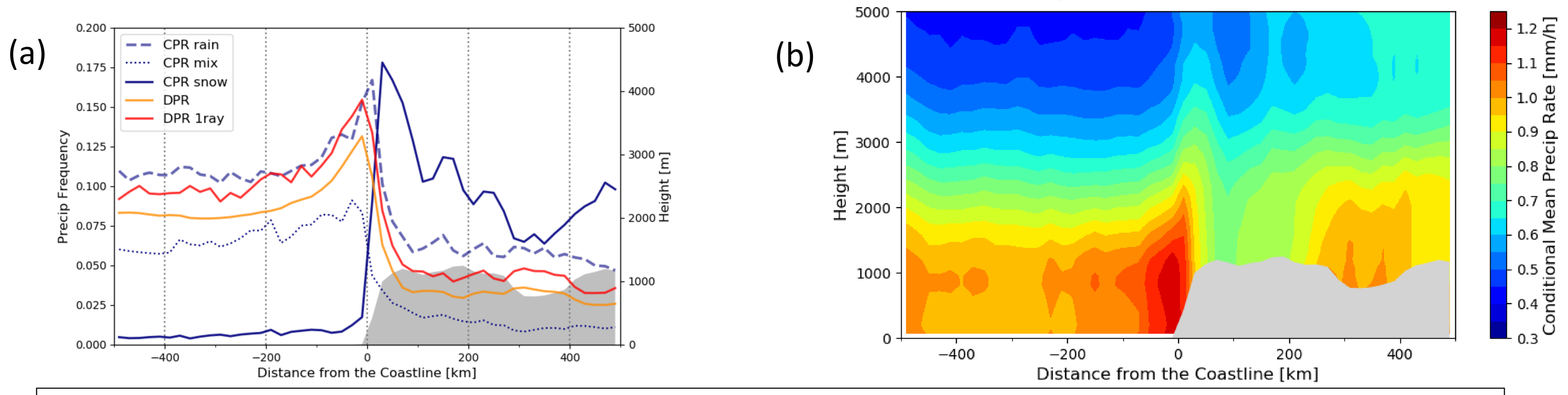
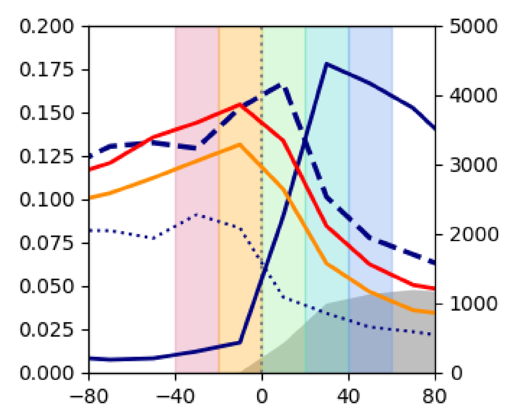


Figure 3. Relationship between the distance from the coastline and (a)CPR-precipitation frequency in each precipitation type (rain/mixed phase/snow) and KuPR-precipitation frequency (all angle bin/one nadir angle bin) , (b)vertical profile of conditional mean precipitation rate.

We classified each precipitation events detected by CPR into 3 cloud types, following Kulie et al. (2016): shallow cumuliform, nimbostratus and other clouds (Fig. 4). Figure 5c,d shows that nimbostratus clouds from seaside are weakened, besides shallow cumuliform clouds are enhanced on the coastal mountain, and most of the echo from these clouds is too weak to observed with KuPR.



Enlarged view of Fig. 3a

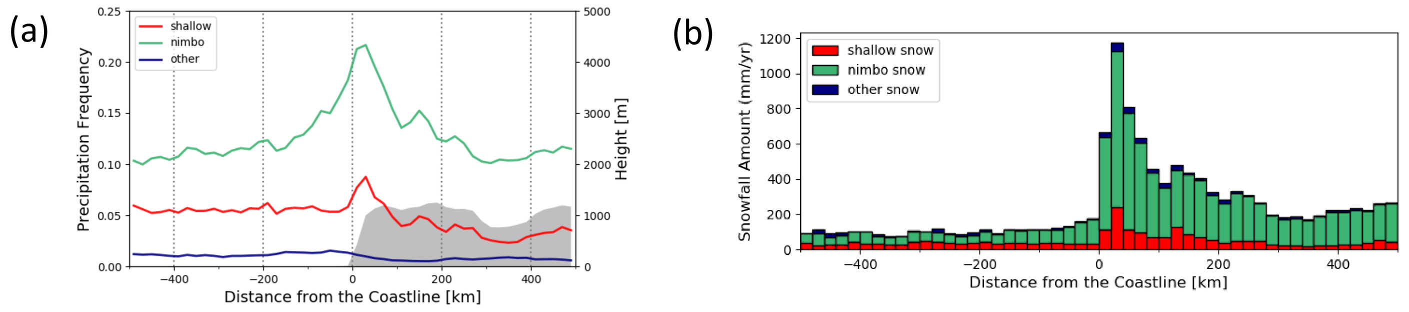


Figure 4. (a) CPR-precipitation frequency and (b) CPR-snowfall rate in 3-type of clouds. Precipitation in the target area is mainly brought by nimbostratus clouds ,which may be linked to storm activity.

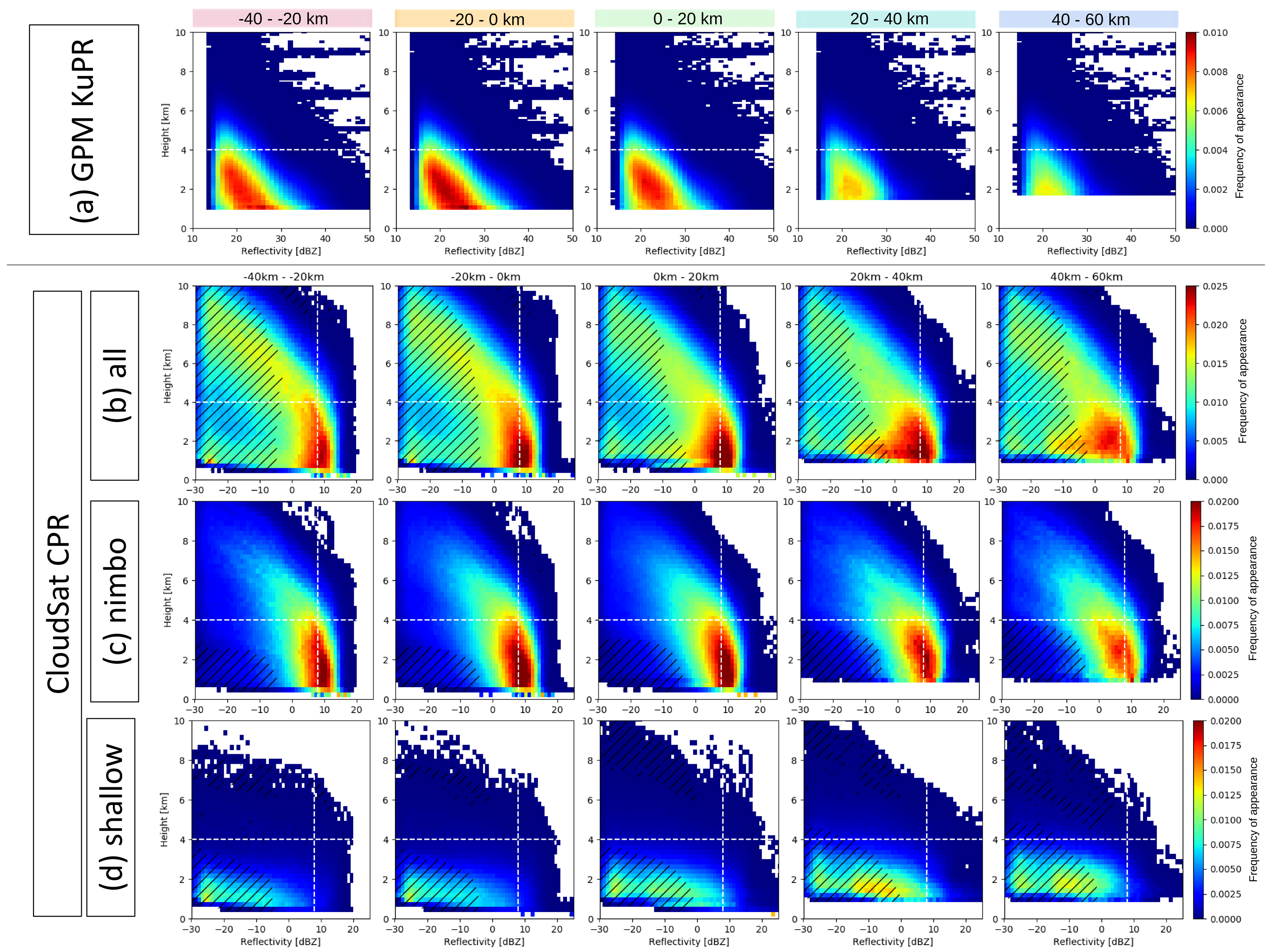


Figure 5. CFADs (contoured frequency and altitude diagrams (Yuter and Houze 1995)) of (a)KuPR reflectivity, CPR reflectivity in (b) all, (c) nimbostratus, (d) shallow cumuliform cloud type in each distance from the coastline. 2D-histograms of reflectivity profile in 1-dB interval and the vertical resolution is (a)125m and (b)240m. Each CFAD is normalized by the number of observation in the respective area. Hatched areas in (b-d) indicates bins where ratio of the number of precipitation events to that of observed events is under 50%. White dashed line on 8 dBZ in (b-d) is the threshold KuPR may detect the echo.

4. Storm activity and moisture convergence

Figure 6 shows that DPR precipitation frequency is largest in autumn (SON). The Gulf of Alaska, which is so called the "graveyard of Pacific storm", has high storm track density, and especially, extratropical cyclones more frequently exist in the Gulf of Alaska in autumn (Mesquita et al. 2009). These facts indicate that the coastal mountain inhibit fronts and south-westerly moisture flows with extra-tropical cyclones in the Gulf of Alaska, and most of the moisture condense over the sea and low land near the coast to produce precipitation. A case shown in Fig. 7 agree with this view. At low level, moisture and converging system approaching to the coast was blocked by the terrain and results in the precipitation above the sea and coast. Upper wind is not blocked on the other hand, thus precipitating clouds around the coast are carried into mountain range by this wind, causing light precipitation there.

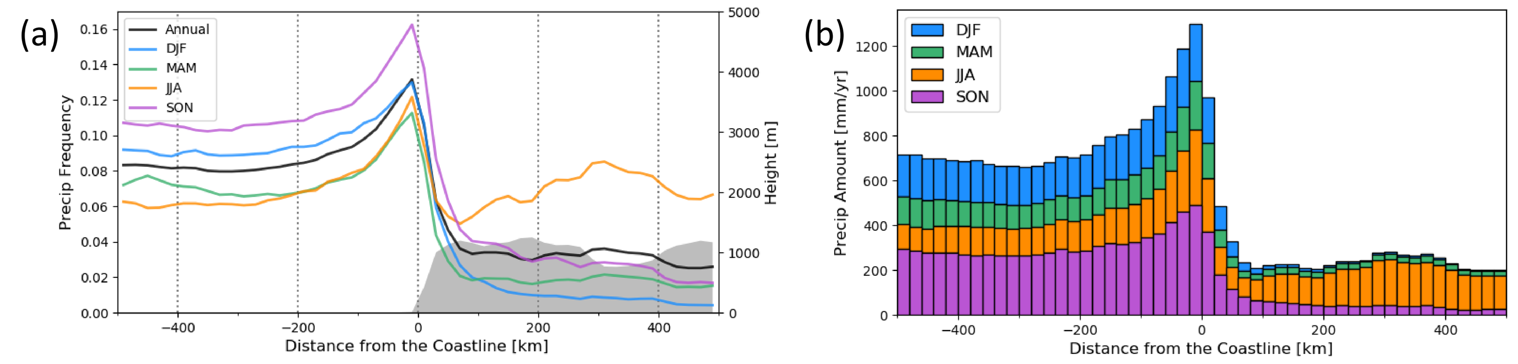


Figure 6. Relationship between annual and seasonal mean KuPR-precipitation (a) frequency and (b) rate.

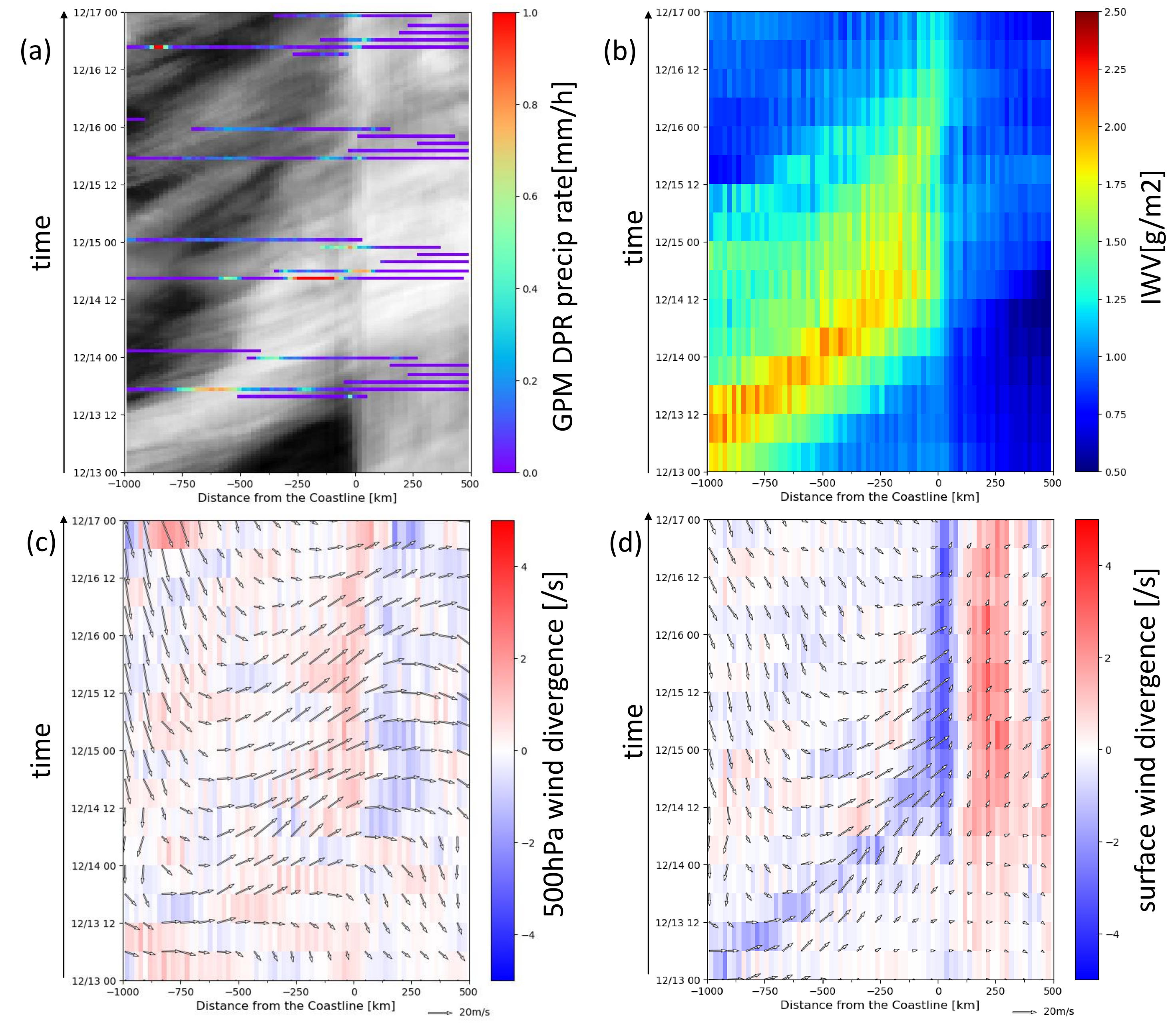


Figure 7. Time-distance diagrams of an approaching warm front for a case on 13th-16th Dec. 2014. (a) GOES-15 IR ch04 and DPR near surface precipitation rate, (b) IWV (Integrated water vapor), (c) 500hPa and (d) surface wind divergence and wind vector (x-axis : cross-barrier wind velocity, y-axis : parallel-barrier wind velocity).

5. Conclusion

We examined around the coast of Alaska by using spaceborne radar dataset, and revealed that:

- **Relatively heavy precipitation from nimbostratus clouds, which can be detected by KuPR, frequently occur above the coastal water.**
- **Frequent snowfall on the coastal mountains are mainly brought by nimbostratus clouds advected from the coast and orographically enhanced shallow cumuliform clouds, which are well detected by CPR but rarely detected by KuPR.**
- **Frontal system and moisture flow associated with extratropical cyclone which come from the Gulf of Alaska are blocked by terrain and stagnate around the coast. This leads to the frequent precipitation around the coastline.**