Questioning the importance of the cloud lifetime effect: The relative roles of drizzle and the sun

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Introduction

In marine environments with low concentrations of CCN, the cloud lifetime hypothesis postulates in part that more precipitation causes decreased cloud fraction (all other factors being equal). Previous work has highlighted examples of the co-occurrence of open-cellular broken cloud with heavy drizzle and suggests that precipitation *is a necessary but not sufficient condition* for marine stratocumulus (Sc) cloud breakup at night. Marine Sc exhibit a strong diurnal modulation of drizzle and cloudiness. We utilize ship and satellite-based observations to examine the joint variation of the diurnal cycle, drizzle, cloudiness conditions, and cloudiness transitions as a test of the cloud lifetime effect in low marine Sc clouds.

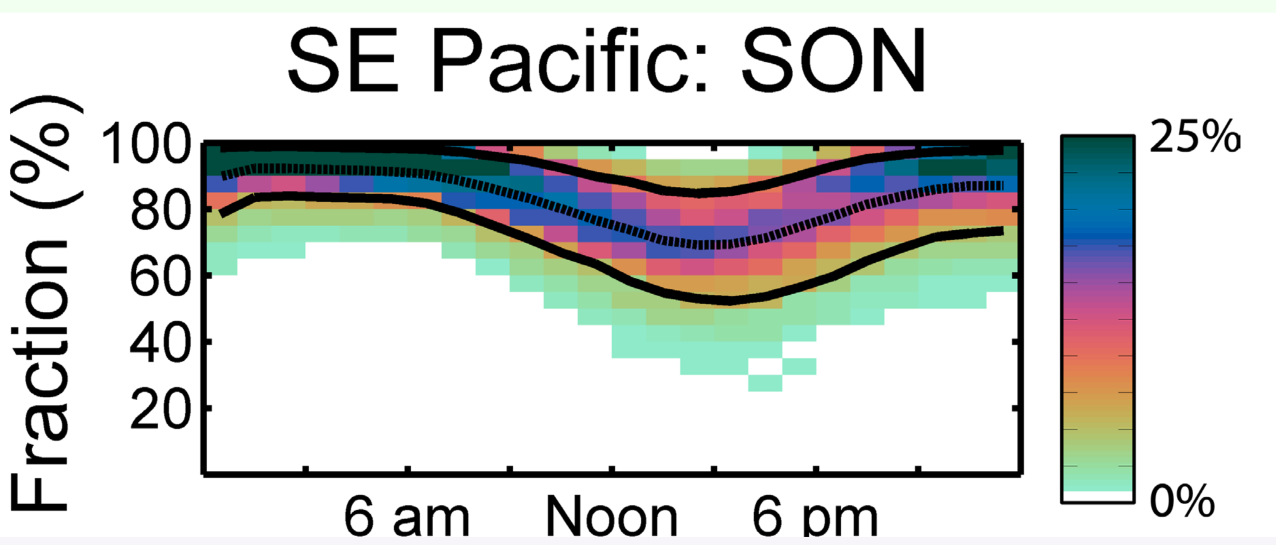
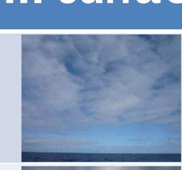
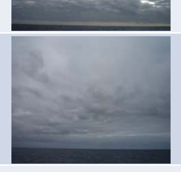


Fig. 1. Frequency distribution of low cloud fraction (CF) across the diurnal cycle for 26 3° × 3° boxes in the southeast Pacific. Solid black lines indicate the 10th and 90th percentiles and the dotted line indicates the hourly mean. [8 years × 3 months = 24 months of data]

Table 1. Radar data sample sizes

Cloudiness Condition	# hours (day)	# hours (night)	Example view from surface
< Scattered (< 75% CF)	73	34	
Broken (75%<CF<100)	51	33	
Overcast (CF=100%)	101	156	
Transition (changing states over 4 hrs)	12	24	

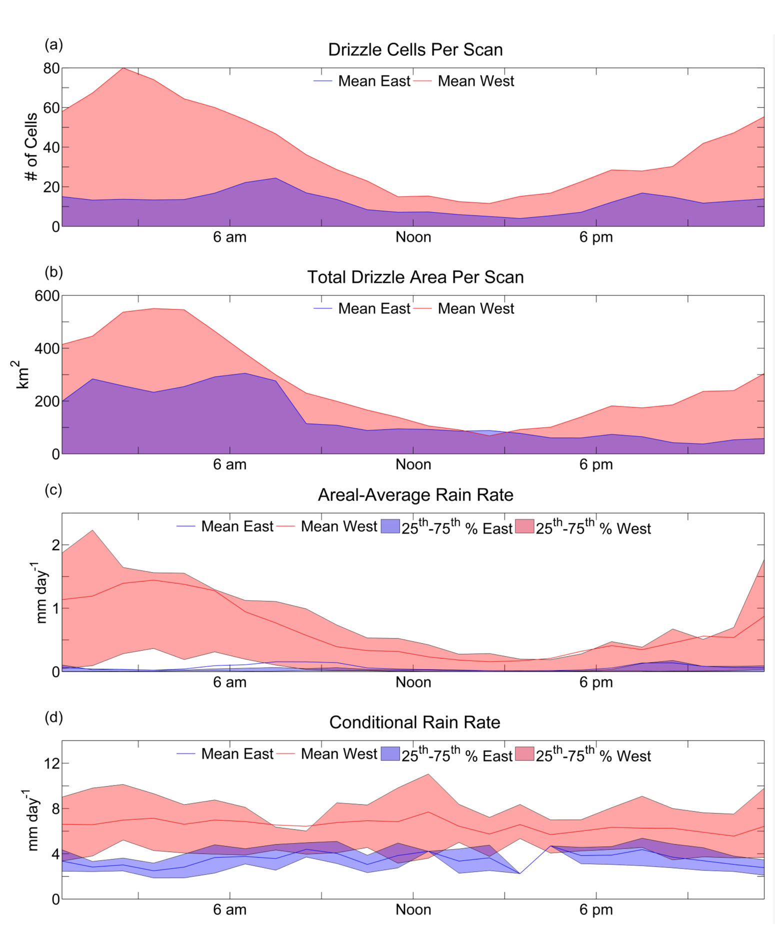


Fig. 2. Ship-radar observed diurnal variation of a) the mean number of drizzle cells per scan, b) the mean total precip. area, c) the hourly averaged rain rate and d) the conditional rain rate. From Burleyson et al. (2013,JAS). **Areal rain rate and the number of drizzle cells peak between 0-3 am and are at their lowest values between 2-5 pm.**

Data Sets

- C-Band radar data collected within a 120 km diameter domain during VOCALS-REx cruises (31 days in Oct. & Nov. 2008) by the NOAA ship Ronald H. Brown. Drizzle cells are tracked and analyzed via an automated algorithm.
- Cloud fraction is determined from a merged geostationary satellite 12 μm IR cloud mask product at 4 km × 4 km spatial resolution and 30 minute temporal resolution.

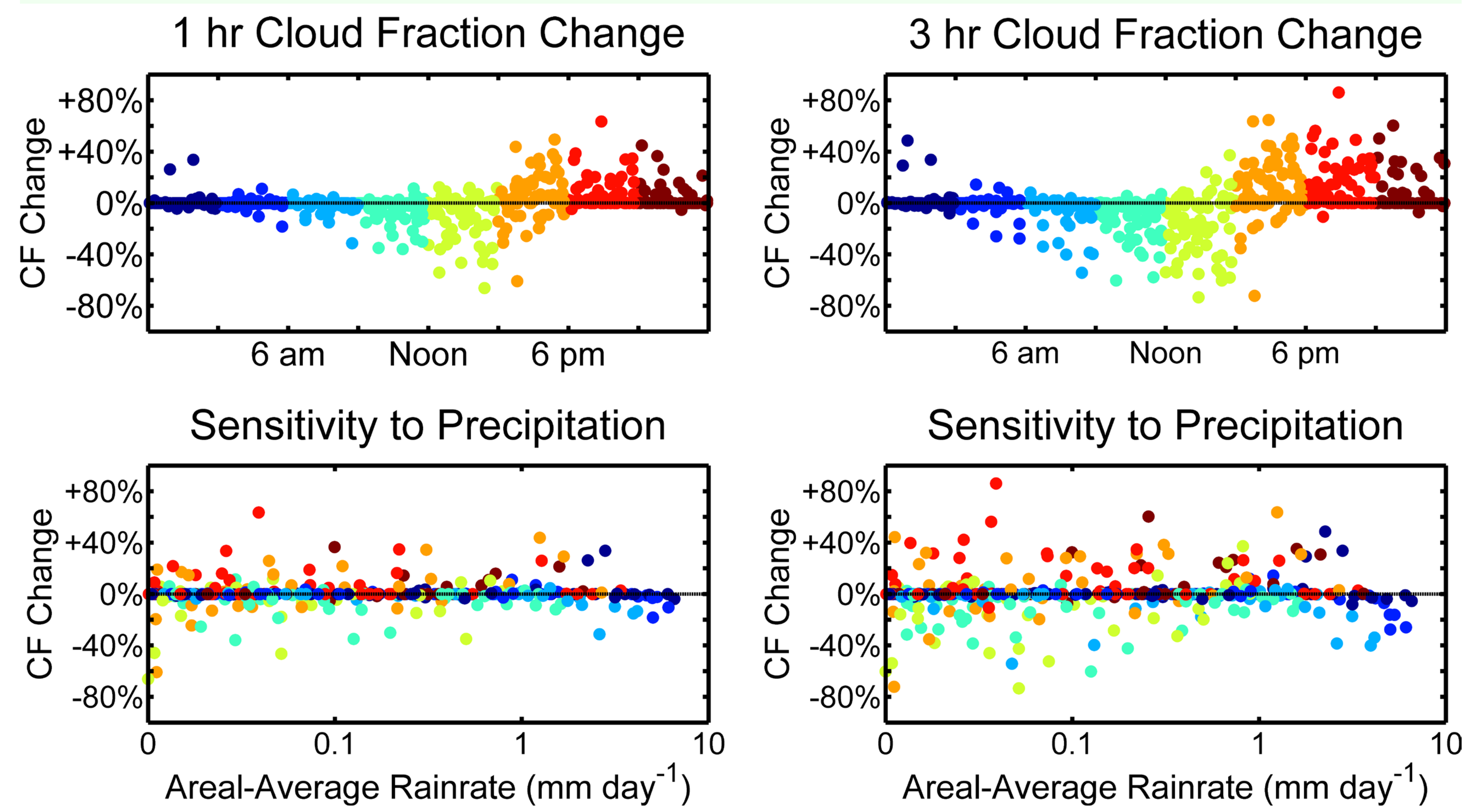


Fig. 3. Cloud fraction change over 1-hr (289 samples) and 3-hr (306 samples) as a function of time of day (color coded) and average precipitation within 60 km of the ship. Cloud fraction is closely associated with the shortwave diurnal cycle. Less than 3% of samples between 6 pm and 6 am have CF decreases more than 5%. **Large decreases in cloud amount occur preferentially during the day with little dependence on precipitation.**

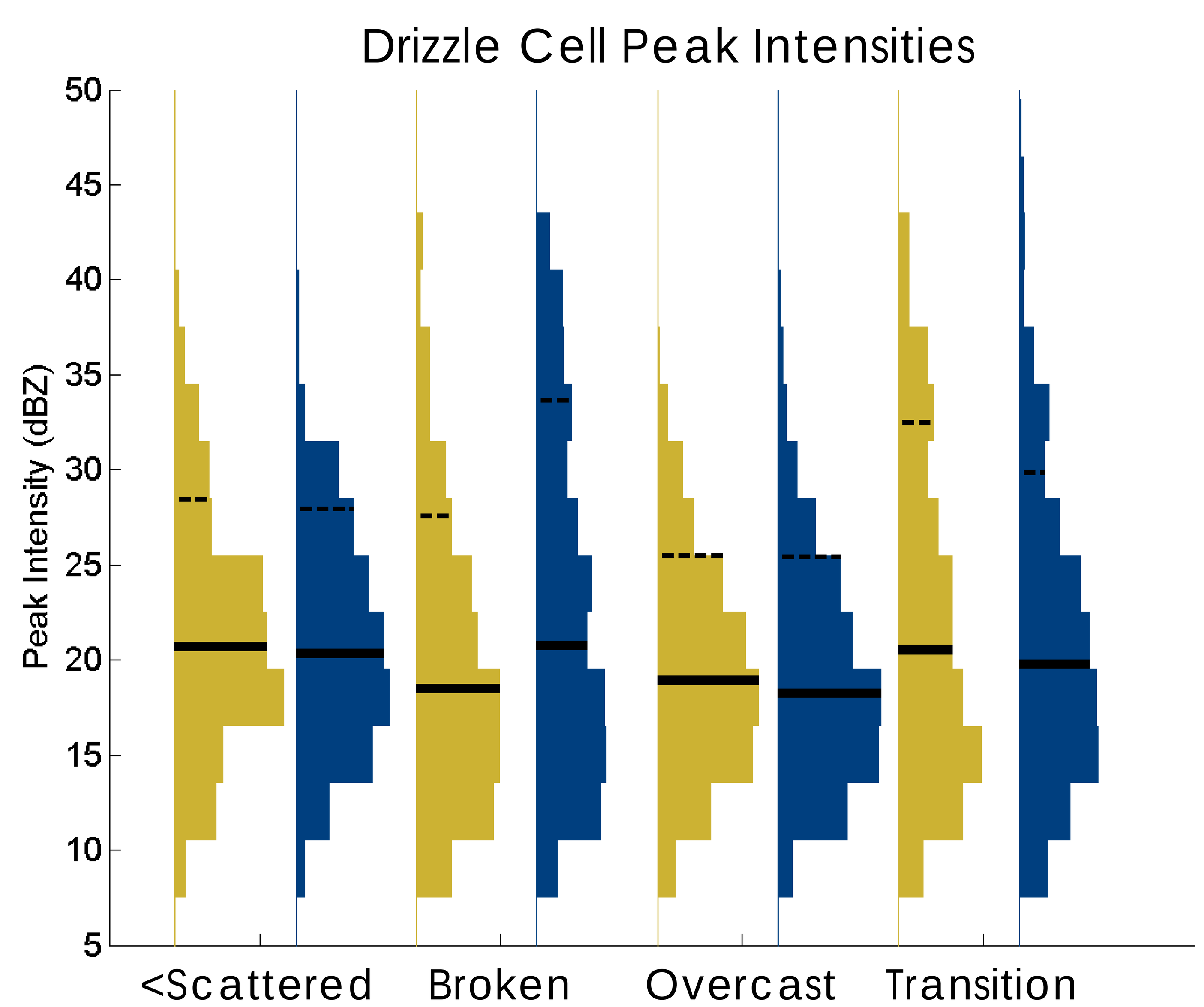


Fig. 4. Relative distributions of drizzle cells peak intensities along cell tracks as a function of cloudiness condition and day (yellow) and night (blue). **Drizzle cell intensity median values** (solid lines) **are similar across all cloudiness/day/night conditions**. 85th percentiles (dashed lines) are highest in broken clouds at night and transitions during the day. 85th percentiles are similar day/night for scattered and overcast conditions.

Conclusions

- Anecdotal examples can be found for a variety of cloud fraction trend and precipitation area conditions.
- Median drizzle cell intensities are similar (19.5 dBZ ± 1.25 dB) across all cloudiness/diurnal conditions. Differences are present in intensity distribution outliers (> 85th percentile).
- At night:
  - Overcast conditions with/without precipitation usually do not break up; CF typically increases
  - Overcast cloud breakup can occur without precipitation

  During the day:
  - Clouds with larger precipitation areas tend to maintain their existing cloud fraction (likely thicker clouds)
  - Clouds with smaller precipitation areas are more likely to co-occur with a cloudiness transition (likely thinner clouds)
  - Rate of CF decrease is closely associated with changes in SW fluxes.
- At 100-300 km and < 5 hour scales:
  - Drizzle and cloud fraction co-vary with the diurnal cycle of solar radiation
  - Drizzle is neither necessary nor sufficient for reducing cloud fraction overnight

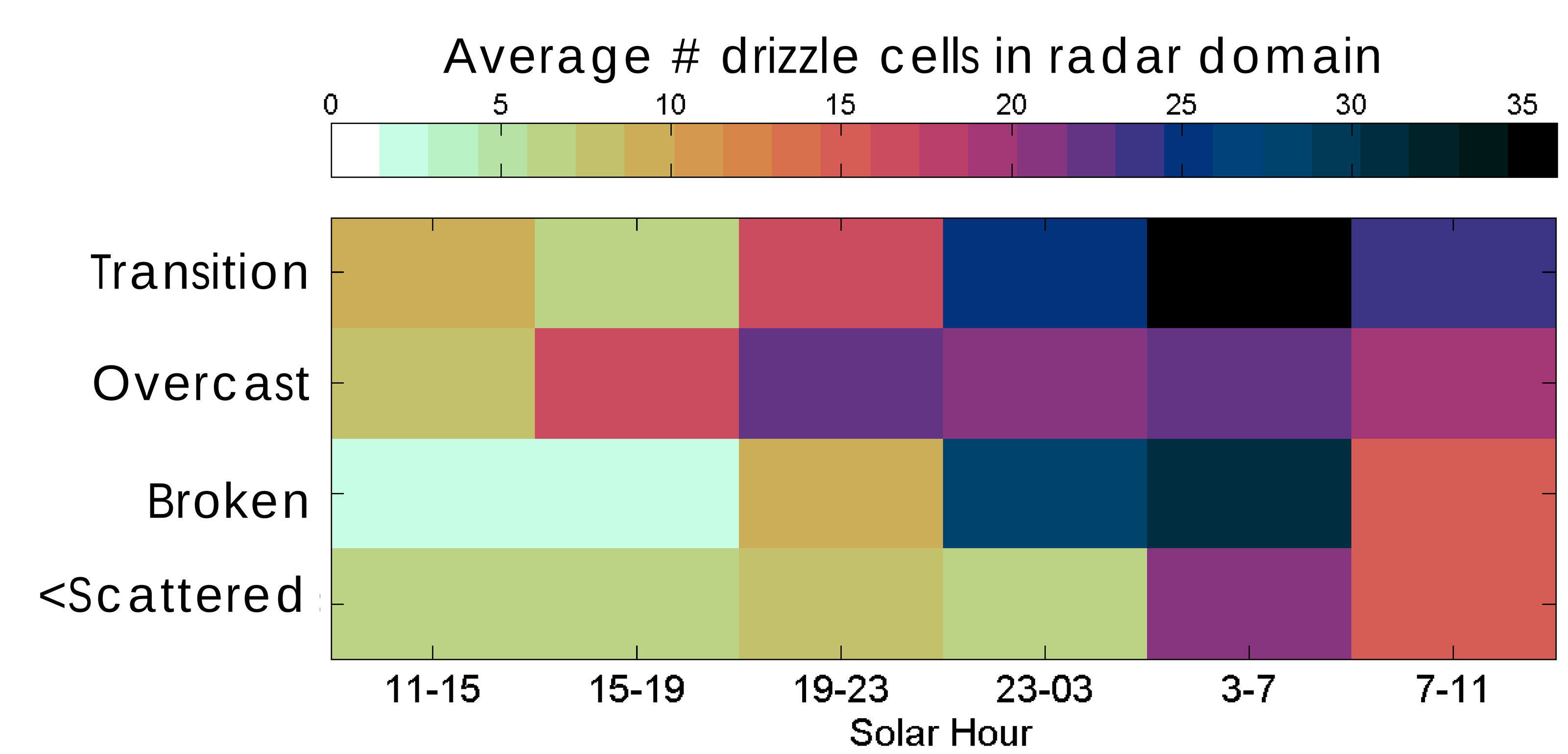


Fig. 5. Average number of drizzle cells within 60 km of ship by time of day and cloudiness condition. **Drizzle increases for all cloud conditions at night. Overcast conditions have more drizzle before midnight than other conditions.** From 11 pm-7 am, the number of drizzle cells increases within transition and broken conditions. After sunrise, more drizzle cells are present in transition and overcast conditions than in other conditions.

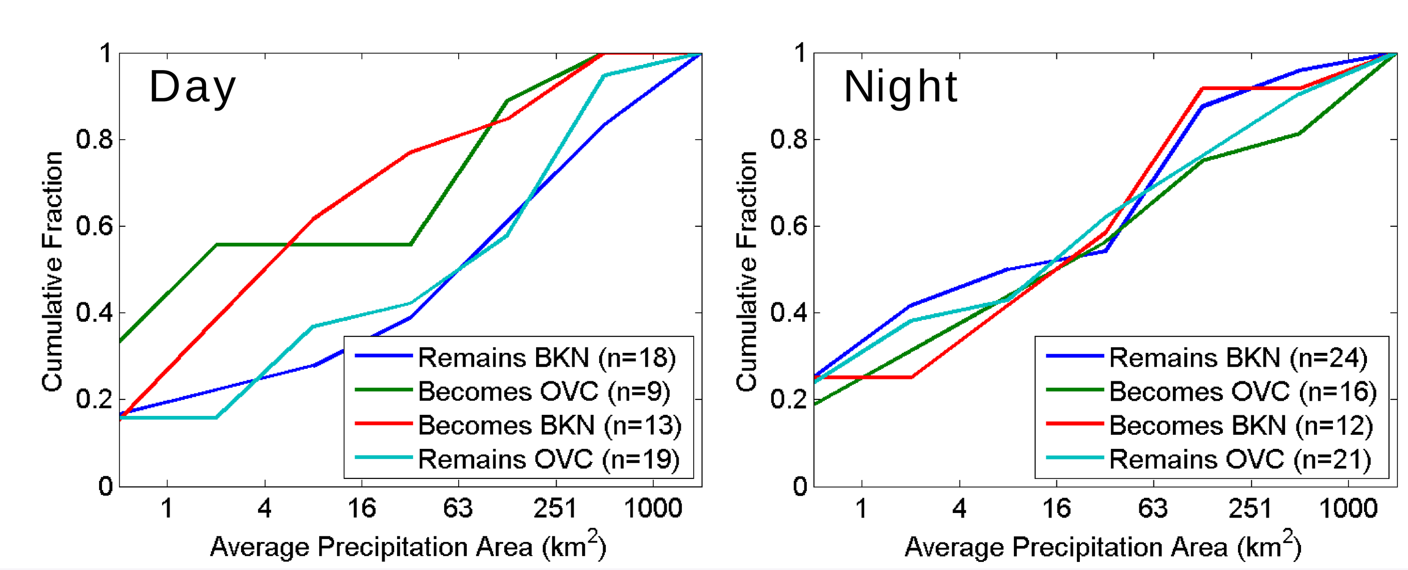


Fig. 6. Cumulative probability distributions of 4-hr average precipitation area trend by cloudiness condition for night (left) and day (right). Broken category includes scattered, transition and broken. **At night, for a given drizzle area, a change or persistence of cloudiness is equally likely. During the day, cloudiness transitions are more likely to occur at times with *less* precipitation**.