P1.134 THE CLIMATOLOGICAL SIGNIFICANCE OF EXTRATROPICAL TRANSITIONING ON TYPHOON PRECIPITATION OVER JAPAN

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1. INTRODUCTION

Extratropical transitioning (XTT) is a frequent occurrence for typhoons in the Northwest Pacific Basin (Fig. 1). XTT has a strong dependence on latitude that is correlated to the poleward increase in baroclinicity combined with the increased likelihood of interacting with upper-level troughs or shortwaves in the Westerlies as well as decreased sea surface temperatures (SSTs). Seasonality is also important and is correlated to the poleward (equatorward) movement of the baroclinic zone during the peak (beginning/end) of the tropical cyclone season as well as to SSTs.

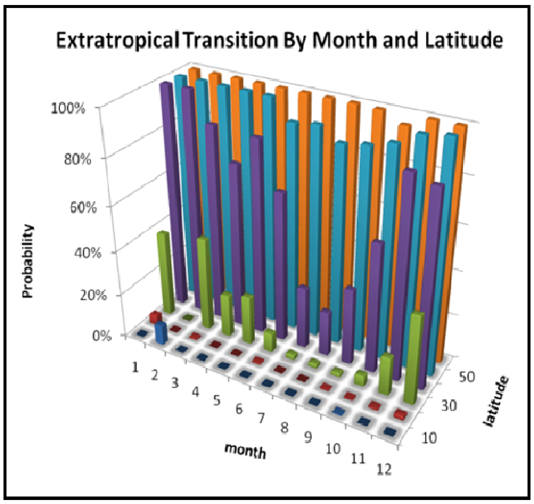

Fig. 1. Cumulative probability of XTT by month and latitude in the Northwest Pacific Basin.

XTT Events in this study are defined as typhoons that transition within 500 km of Japan's Coast while nonXTT Events are defined as typhoons that come within 500 km but which do not transition. Transitioning times and locations are based on Japanese Meteorological Agency (JMA) best track data.

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Japan experiences four landfalling typhoons with an additional four near misses (bypassers) on average each year. The high frequency and mid-latitude location means Japan experiences many XTT typhoons (55% XTT vs. 45% nonXTT) each year as shown in Fig. 2 for the period 1951-2008. There have been even more XTT events recently (cf. Table 1).

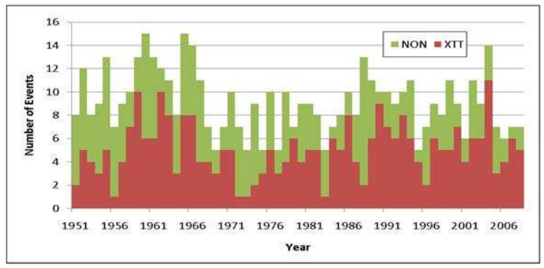

Fig. 2. Number of historical XTT and nonXTT events for Japan.

Japan is a highly developed country, with a mature insurance market, a lot of coastal exposure and susceptibility to typhoon precipitation-induced flooding. For all of these reasons, XTT can be very important for Japan (cf. Jones et al. 2003), particularly from a precipitation perspective, which is the focus of this paper.

Figure 3 illustrates some characteristic features of XTT Typhoons by comparing XTT and nonXTT storms. For example, during XTT, forward speed can increase dramatically, (compare track points of Faxia 2007 to those of Mawar 2005). The increased translation speed is related to the increased windspeed aloft, which in turn is related to the increased baroclinicity below.

Events	XTT	nonXTT
1951-88	176	176
1989-08	116	61

Table 1. Summary statistics of XTT and nonXTT events shown in Fig. 2.

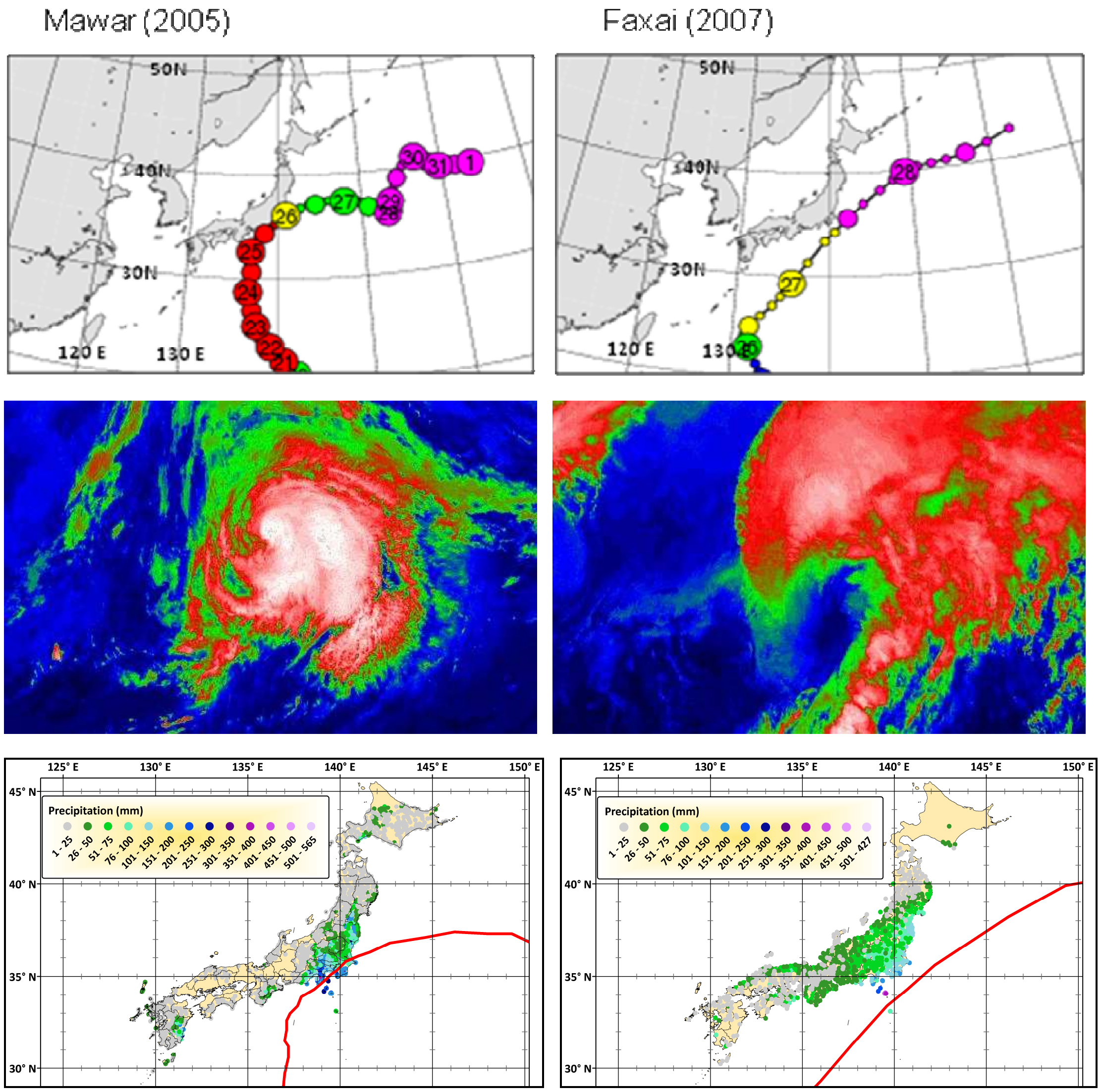

Fig. 3. Comparison of Mawar (nonXTT) and Faxia (XTT) events from a track (top row), enhanced satellite imagery (second row), and AMeDAS precipitation perspective (third row).

Typhoons are usually associated with symmetric cloud shields (Fig. 3 – middle left panel) and dense convection surrounding the center as exhibited by Mawar. During XTT, baroclinic energy conversions cause the TC to increase in size and to exhibit an asymmetric, comma-shaped cloud pattern (Harr et *al*. 2000) as shown by Faxia (Fig. 3 – middle right panel). This pattern is accentuated by overrunning of warm air that can cause the cloud shield and precipitation to expand poleward and by dry air entrained into the southwestern flank (in the northern hemisphere).

Observed precipitation from Japan's Automated Meteorological Data Acquisition System (AMeDAS) demonstrates that Mawar's heavy precipitation fell over a slightly larger area of Japan while the overall precipitation footprint was smaller than Faxia's (compare bottom row panels in Fig. 3). The larger footprint of Faxia likely occurred from overrunning and southwestward extension of the comma-head cloud mass with time.

The Tropical Rainfall Measuring Mission (TRMM) Data is another source of observed precipitation and shows nonXTT precipitation amounts in Mawar are higher and symmetric about the track while XTT precipitation in Faxai is more diffuse, slightly lower, and skewed north of the track (not shown). Comparison of TRMM and AMeDAS data shows good agreement at the event level.

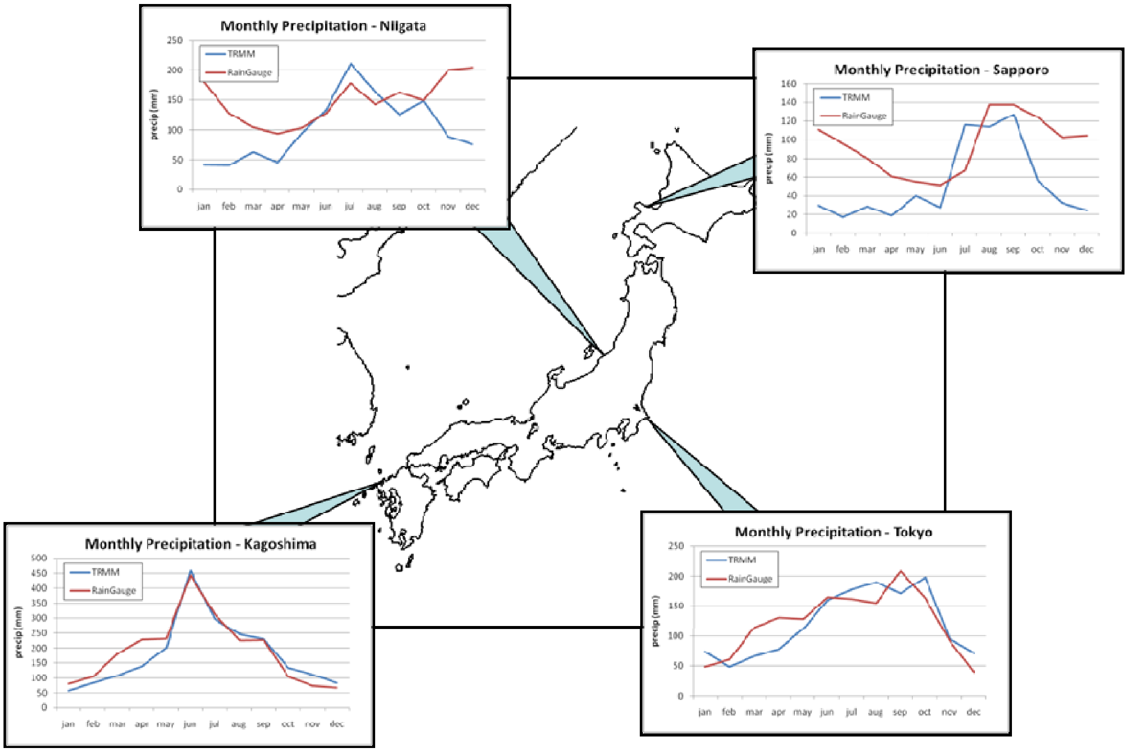

Fig. 4. Comparison of TRMM and rain-guage derived monthly precipitation totals for selected cities in Japan.

2. USING TRMM DATA

This study makes use of TRMM data available for the period 2000-2008. One advantage of this data is that it provides (gridded) precipitation information over water. While that precipitation is not necessarily part of Japan's Precipitation Climatology, it adds insight as to the physical processes that are associated with the extratropical transitioning process.

One potential concern with using TRMM data is that it is not measured directly (with a rain gauge). To evaluate the effective impact of that concern, monthly precipitation totals were computed for various locations in Japan.

A sampling of the results is shown in Fig. 4. For stations located south of Mid-Honshu (e.g., Tokyo), there is very good agreement between 1971-2000 rain-gauge and 2000-2008 TRMM totals given the fact that two different time periods are evaluated. The good agreement is consistent with results from Bowman (2005).

3. IMPACT FROM AN EVENT PERSPECTIVE

Figure 5 shows that TRMM-based annual average precipitation totals from XTT events are considerably higher than those from nonXTT events, which is primarily the result of there being nearly twice as many XTT events as nonXTT events. The largest differences exist in southern Honshu despite the fact that the biggest jump in percentage of XTT events occurs north of 30° N. The XTT precipitation footprint is also significantly wider, which may be a result of more diverse tracks and / or wider event-footprints.

Figure 5 also shows that event average precipitation for XTT events is also significantly heavier (e.g., by 40-50 mm) than that from nonXTT events. Again, significant differences exist for southern Honshu. The fact that differences are greatest in southern Honshu - where storms have not likely completed their transitioning, suggests that some process relevant to transitioning may be responsible for generating the heavier precipitation. That process could be the formation of a baroclinic leaf (Carlson, 1991).

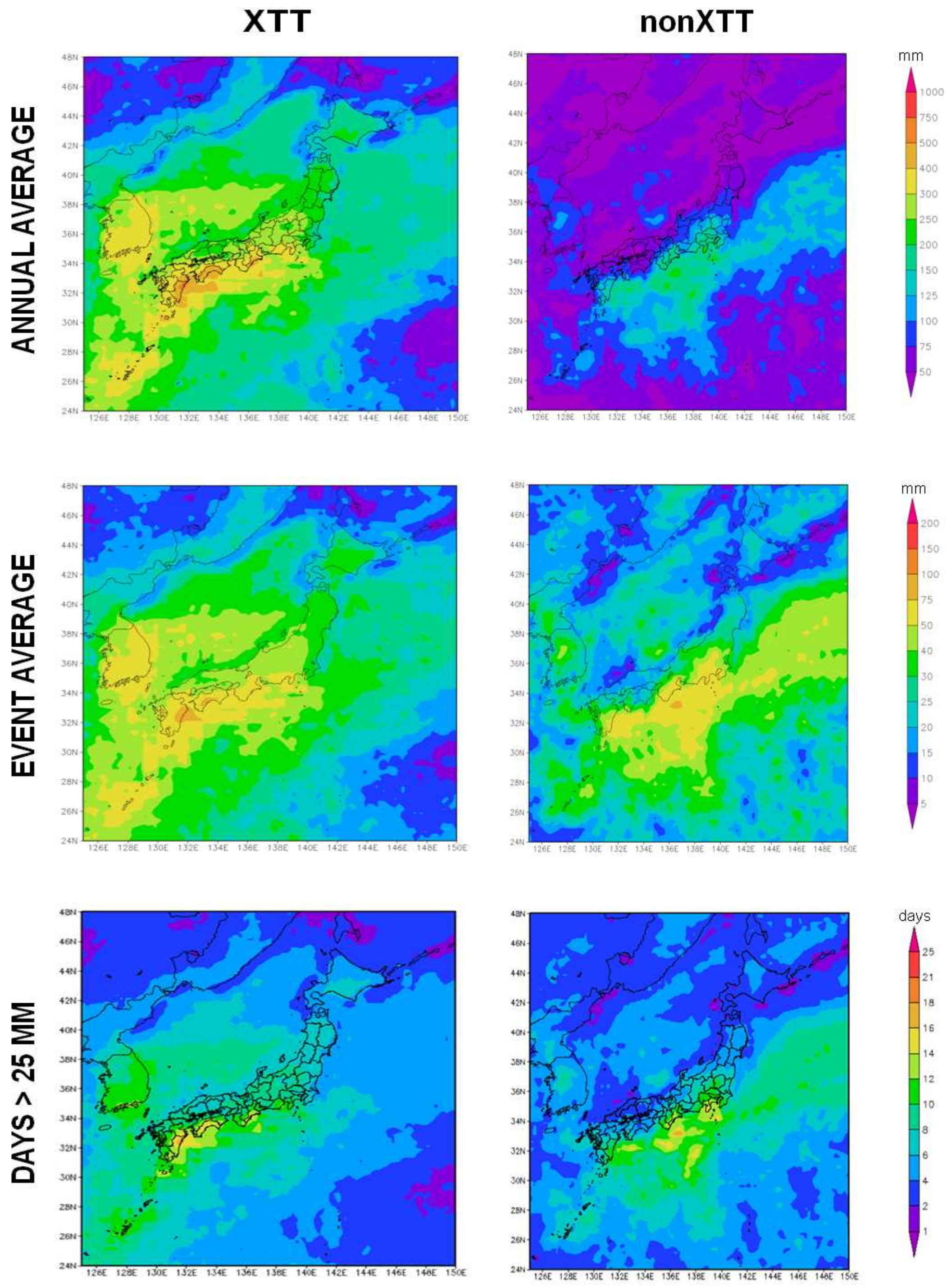

Fig. 5. TRMM-based comparison between XTT and nonXTT events for annual average precipitation (top row), average precipitation per event (middle row), and days per season with precipitation totals over 25 mm.

Finally, Fig. 5 shows that XTT event precipitation also benefits from more days with heavy precipitation (> 25 mm). Again, in southern Honshu and Shikoku, it can be seen that there were 14-16 days with >25 mm of precipitation from XTT events and fewer than 10 days in this region from nonXTT events. It is also noteworthy that for all of the three analyses shown in Fig. 5, XTT precipitation amounts are heavier over S. Korea, which may suggest that typhoons that enter the Sea of Japan undergo XTT more readily.

4. STORM RELATIVE XTT PRECIPITATION EVOLUTION

An analysis was performed to evaluate the precipitation contribution based on the transition phase of XTT events. A storm relative perspective was generated using the 52 XTT events from 2000-2008. The corresponding three-hourly TRMM precipitation grids were all aligned to be storm-relative (based on JMA storm-track positions – shown by X's in Fig. 6) at the time of XTT again according to JMA (t-00), as well as 24 and 48 hours earlier and 24 hours later (t-24, t-48, and t+24 respectively).

The t-48 phase corresponds to the storm still being a warm-core tropical cyclone (Klein et al. 2000). The storm-relative precipitation footprint shows a quasi-circularly symmetric envelope. The t-24 phase represents an event beginning transition. The precipitation envelope indicates a crescent elongated towards the northeast, representing the development of the comma head. The t-00 phase represents the complete transition of the storm. The corresponding precipitation shield illustrates the mature comma head as well as evidence of the comma-tail (cold front). As this latter feature is of smaller scale and is likely oriented differently with each event, it is much more diffuse. The t+24 phase represents the logical extension of most XTT processes – a more diffuse yet contracted version of the t+00 phase.

5. IMPACT FROM A PHASE PERSPECTIVE

A different perspective of XTT precipitation is shown in Fig. 7, where the precipitation just from XTT events is divided up into pre-XTT and post-XTT phases, again based on the JMA-provided XTT times. The JMA-00 perspective uses the JMA times to divide the precipitation into pre- and post-XTT periods.

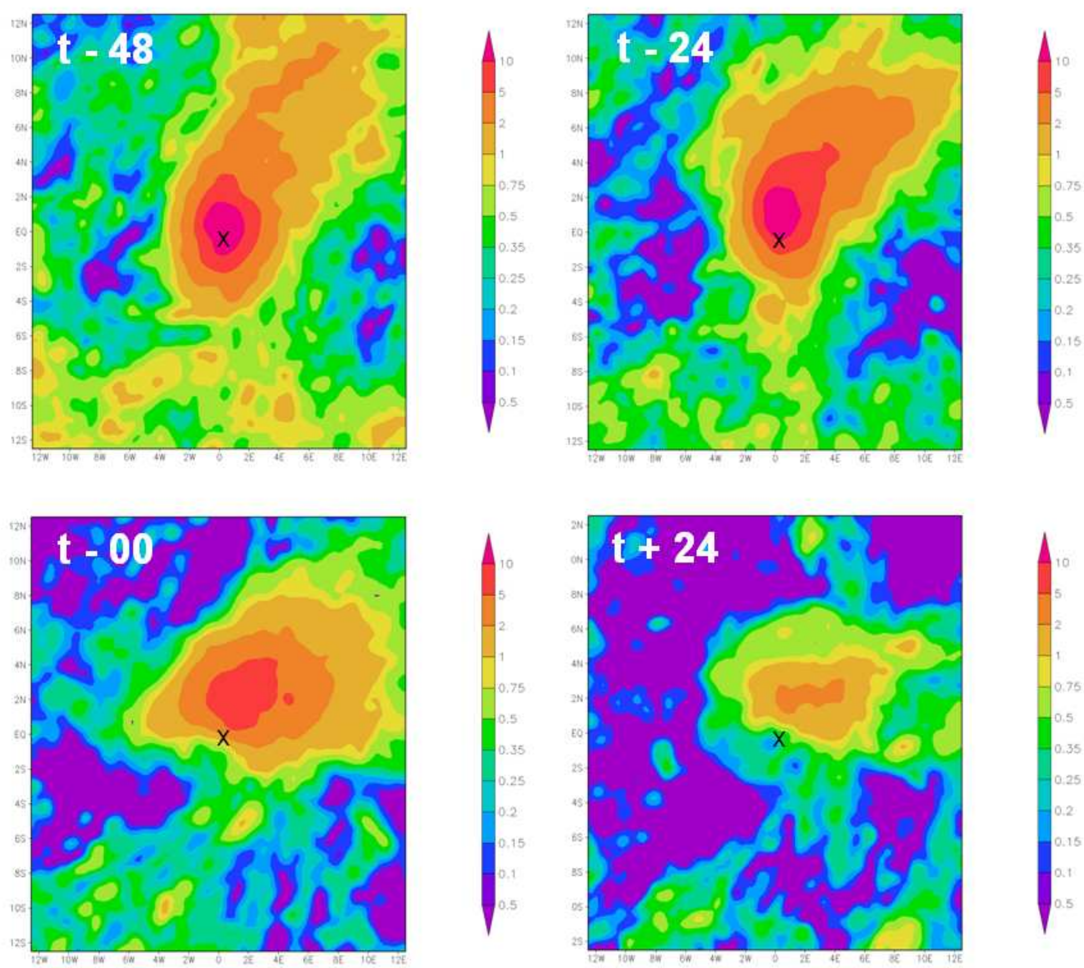

Fig. 6. TRMM-derived storm-relative precipitation per event totals at four different stages of XTT transition. Stages are as described in text.

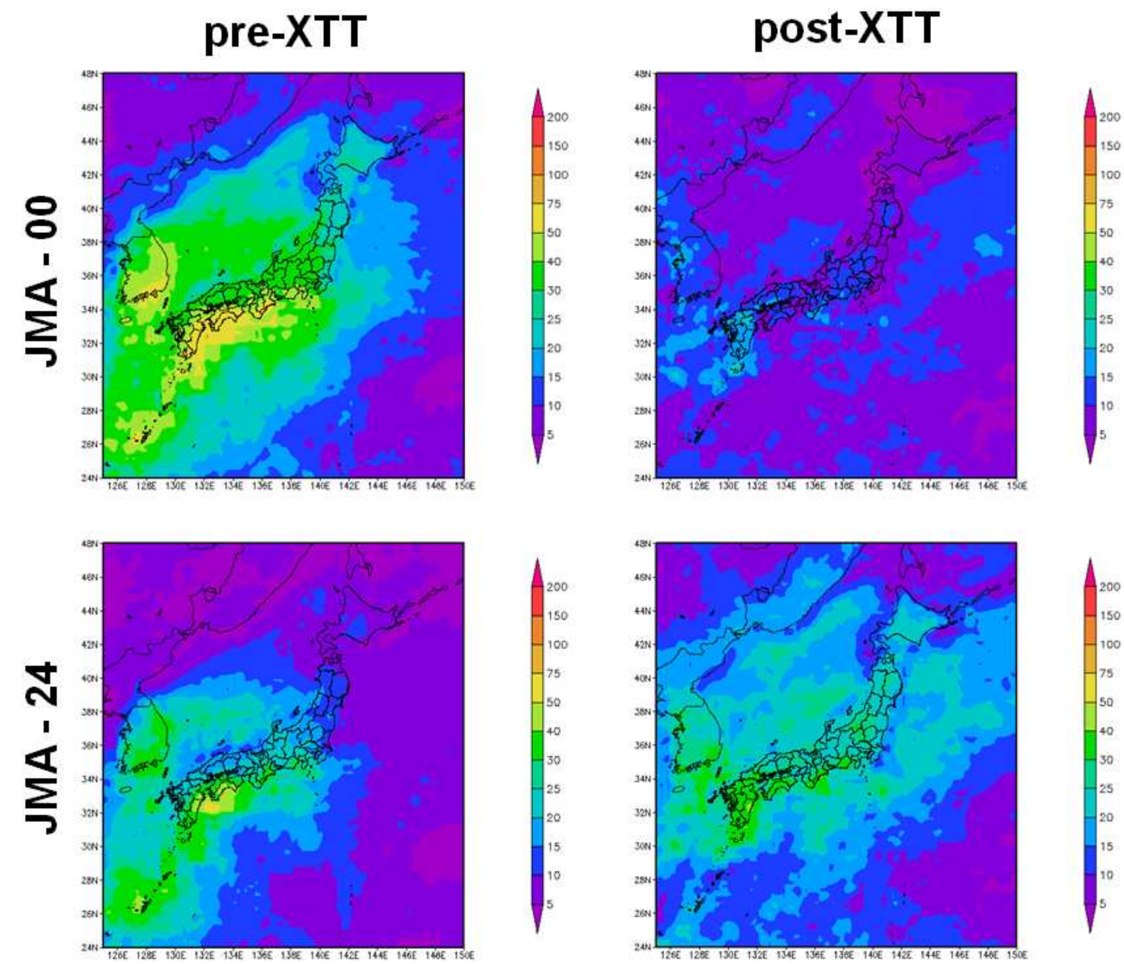

Fig. 7. TRMM-derived precipitation per event for pre- and post-XTT periods as defined by the JMA (JMA-00) and also by assuming transition occurred 24 h earlier (JMA-24).

The JMA uses criteria for determining XTT which may or may not be entirely appropriate for our precipitation focus presented here. Other perspectives such as that outlined by Hart (2003) typically show transitioning times that are earlier than what JMA show, by 12-24 h on average. Inspection of available satellite imagery for the period 2000-2008 also support earlier XTT times.

The JMA-24 results assume that transition has occurred 24 hours earlier than what JMA has indicated. While the JMA-00 shows a considerably smaller portion attributed to post-XTT phase, the JMA-24 perspective shows a much more equitable division. Over Hokkaido, most of the precipitation falls during the post-XTT phase.

6. A LONGER PERSPECTIVE FROM AMEDAS

Although limited to on-land stations, the AMeDAS perspective is useful for demonstrating the relative contributions from XTT events and nonXTT events for a considerably longer time period (1981-2008). The results shown in Fig. 8 agree qualitatively with those from TRMM - even over Hokkaido.

7. IMPACT ON LOSSES

Figure 9 illustrates AMeDAS-derived event-average precipitation from 2000-2008, broken down by XTT and nonXTT. The mean storm track for typhoons which impact Japan is along the south and east coast. Thus, typhoon precipitation is greatest in those coastal regions and greater, on average, for XTT tropical cyclones because of the higher frequency. In many cases, XTT precipitation begins falling far ahead of an approaching tropical cyclone, along frontal boundaries that typically set up from southwest to northeast, which is an attribute of pre-XTT tropical cyclones. Japan's highest exposure is also along the south and east coastal regions, which means that XTT tropical cyclones have the potential to cause large amounts of precipitation and flooding. The flood risk associated with tropical cyclones is great enough that extensive flood defense systems have been put into place in most of the larger metropolitan areas.

Flood losses in general are a combined result of severity of the hazard, location of dense exposure, and vulnerability. The losses above, whether from XTT or nonXTT event precipitation, reflect the concentrations of exposure in urban areas (e.g., Tokyo, Osaka, Sapporo).

Figure 10 shows flood loss results from ingesting TRMM total precipitation, for all Japan-affecting 2000-2008 typhoons (broken down by XTT and nonXTT), through AIR's Japan Typhoon Model Version 5.0. The results demonstrate that XTT and nonXTT precipitation cause more or less equal amounts of flood losses throughout Japan. Hokkaido (northern-most island) sees the largest increase in flood loss between XTT and nonXTT precipitation with eastern Honshu seeing

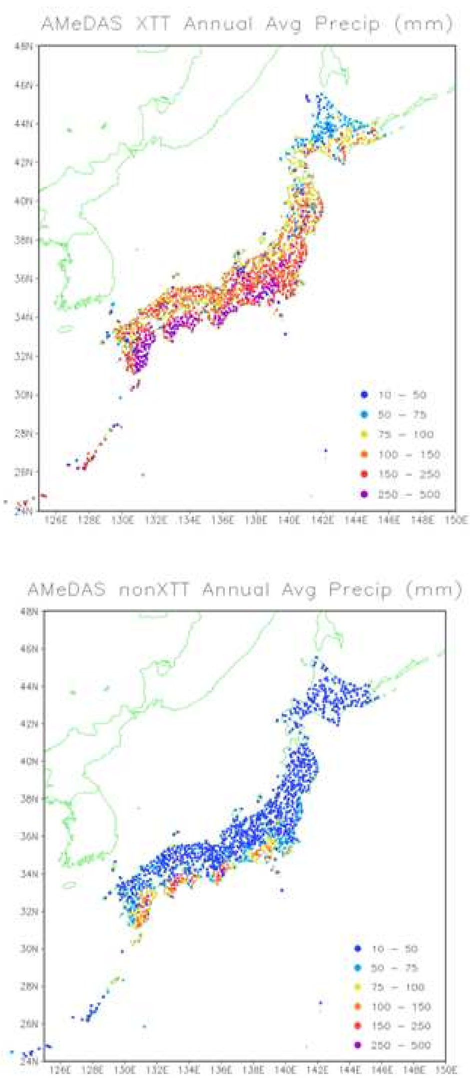

Fig. 8. Comparison of XTT and nonXTT event precipitation from an AMeDAS perspective.

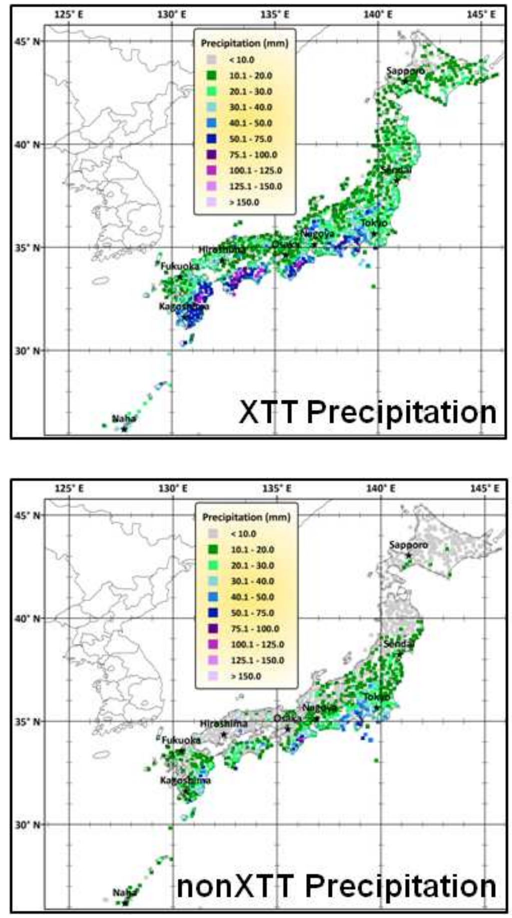

Fig. 9. AMeDAS derived event-averaged precipitation for XTT and nonXTT events.

the largest decrease. A characteristic feature is the increased losses from XTT precipitation for many prefectures facing the Sea of Japan (e.g., northwestward facing coast).

One hypothesis to explain the spatial pattern of losses is that different phases of the XTT process may contribute to the precipitation and loss differences. For example, Kyushu and southern Honshu may have increased losses from XTT precipitation because of the formation of a baroclinic leaf (Carlson 1991) as part of the XTT process early on at these more southern latitudes. The increased losses in Hokkaido from XTT precipitation may reflect the expanded cloud shield associated with the comma head – later in the XTT process (Ritchie and Elseberry 2001, Kitabatake 2008). The decreased losses from an XTT precipitation perspective over central Honshu may be the result of the region being underneath the developing dry slot – at the apex of the comma head and tail – as a typhoon is transitioning. The increased losses from XTT precipitation along the northwestward facing

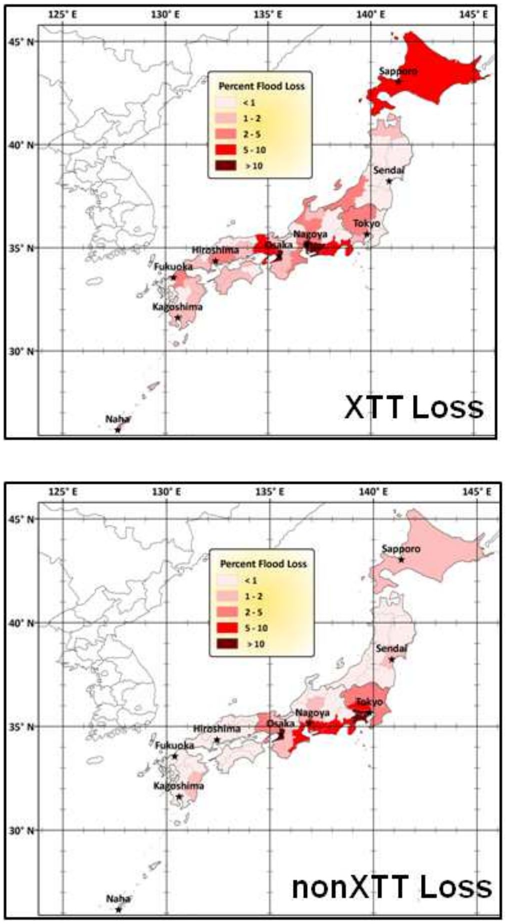

Fig. 10 Estimated distribution of property damage by flood resulting from XTT and nonXTT events.

prefectures are likely attributable to the expanded precipitation footprint extending over that region. It is also possible that, given the rather short length of reliable TRMM data (9 years), and the fact that a handful of events (in both XTT and nonXTT cases) explain close to 90% of the total, these results are unlikely to be statistically significant.

7. CLOSING REMARKS

XTT is a frequent occurrence for typhoons that influence Japan. The portion of precipitation before transitioning has completed is as significant if not more so than the precipitation after transitioning has completed. The analyses performed here are based on transitioning times and locations as recorded by JMA. The JMA uses criteria which may or may not be entirely appropriate for our precipitation focus presented here. Other perspectives such as that outlined by Hart (2003) typically show transitioning times that are earlier than what JMA show, which was the purpose for including the JMA-24 perspective in Section 5. A more precise case-by-case transition time analysis would likely provide clearer results, especially with respect to Section 4 that showed the storm-relative precipitation distribution as a function of transition phase.

The results here provide a climatological perspective of extratropical transitioning that is relevant from an insured loss perspective. Namely, simply assuming that all typhoons that impact Japan generate precipitation as nonXTT events yields a significantly different loss scenario than what XTT events generate. These results also suggest that prefectures facing the Sea of Japan – along the northwest side of Honshu – are as susceptible to precipitation-induced flooding from XTT typhoons as are those prefectures along the southeast side.

Additional research is planned to investigate the specific reasons for the XTT-nonXTT precipitation and loss differences.

Acknowledgements

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