Reply

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We thank Curtis et al. (2006) for further investigating the issue of ENSO-related precipitation variability that was raised in Goddard and Dilley (2005, hereafter GD05). One of the recommendations of GD05 encouraged closer scrutiny of both the climate impacts and the societal impacts of the full range of ENSO conditions, including neutral conditions. GD05 examined ENSO impacts starting with frequency of hydrometeorological disasters, then turning to relative magnitude and extent of precipitation anomalies and finally presenting prediction ability. We found that hydrometeorological disasters overall were not more prevalent during ENSO extremes.[1] We found that the overall perturbation to precipitation over land areas was only weakly affected by ENSO extremes. Most importantly, we showed that the potential predictability of precipitation increases dramatically during ENSO extremes, implying that the potential disasters posed by the precipitation anomalies stand a better chance of mitigation.

Curtis et al. (2006, hereafter C06) take on the second question raised in GD05, namely, "Do climate anomalies become more severe or widespread during ENSO extremes?" Their comment focuses on our, admittedly faulty, implicit assumption that monthly rainfall totals are normally distributed. They are absolutely correct in highlighting this unintentional but major oversight. The specific question to be addressed then is, "Does the [incorrect] assumption of normality invalidate the conclusions of GD05 regarding the impact of ENSO on precipitation anomalies?"

To address that question it was necessary to repeat the calculations on our datasets, as there were several differences between the analyses in GD05 and C06. C06 use percentiles to categorize the precipitation anomalies in order to eliminate dependence on the distribution shape, thereby circumventing the issue of normality. We have employed that approach here, and we agree that this is a more appropriate way to treat the data. Although they do repeat their analysis using the standardized version of the precipitation perturbation index (PPI) as in GD05, some differences in their analysis make it difficult to directly assess the implications of using standardized PPI versus percentile PPI for the conclusion of GD05. These differences include use of a different precipitation dataset and use of different thresholds for categorizing precipitation as extreme. Since C06 use a different precipitation dataset, one cannot conclude whether the values they obtain are specific to that dataset. This is a major reason that GD05 used two different datasets, and we did find differences in the results between the two. If the values obtained using a third are dramatically different, that itself is an interesting result, indicating that too much uncertainty exists in the observations to draw specific conclusions. We are not sure why C06 use a different extreme threshold, but we have repeated our calculations for both thresholds to see if it makes a difference. We have also incorporated their exclusion of climatologically "dry" regions, which had not been done in GD05.

In the percentile version of the PPI, consistent with

[1] ENSO extremes are defined as the upper and lower 25th percentile tails of the Niño-3.4 distribution, or equivalently El Niño and La Niña conditions, respectively.

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TABLE 1. (a) Observed frequencies of categorical monthly mean percentile-based rainfall indices (low: ≤15th percentile; 15th percentile < med < 85th percentile; high: ≥85th percentile) under El Niño, La Niña, and neutral conditions. (b) Similar to (a), but for 10th percentile tails. The first value is based on gridded rainfall data from the CRU-University of East Anglia (CRU-UEA); the second parenthetical value is based on GHCN gridded rainfall data.

Table 1a

	15th percentile tails (PPI)			15th percentile tails (spatial coverage)		
	Low	Med	High	Low	Med	High
El Niño	15% (8%)	69% (77%)	16% (15%)	17% (9%)	64% (68%)	19% (23%)
Neutral	18% (18%)	70% (68%)	12% (14%)	18% (19%)	70% (69%)	12% (12%)
La Niña	9% (15%)	71% (67%)	20% (18%)	7% (15%)	75% (70%)	18% (15%)

Table 1b

	10th percentile tails (PPI)			10th percentile tails (spatial coverage)		
	Low	Med	High	Low	Med	High
El Niño	15% (11%)	70% (76%)	15% (13%)	17% (9%)	68% (72%)	15% (19%)
Neutral	19% (19%)	69% (65%)	12% (13%)	22% (21%)	66% (68%)	12% (11%)
La Niña	8% (12%)	70% (72%)	22% (16%)	6% (17%)	79% (69%)	15% (14%)

C06, precipitation values are ranked over the 1950–95[2] period for each calendar month, converted into percentiles, and then adjusted so that the upper and lower half of the distribution both range from 0.5 to 1.0. Thus, the driest 10% of years would yield values between 0.9 and 1.0, similar to the wettest 10% of years. The level of "extreme" used in GD05 was one standard deviation, or approximately the 15th percentile tails in a normal distribution. Thus, for the percentile version of the PPI, we take the wettest 7 and driest 7 cases out of 46, in a particular calendar month, as representing the extremes. C06 perform their analysis with the 10th percentile tails, so we repeat our calculations also for the 5 wettest/driest cases out of 46. Summary tables (Tables 1a,b) focusing on extreme precipitation (for brevity) are compared with those originally presented in GD05 (Table 2). In comparing with C06, one should also note that their definition of "low," "medium," and "high" in categorizing relative spatial coverage uses quartiles or 25th percentile tails, while we use 15th percentile tails; this does not qualitatively affect the results.

The use of a percentile-based PPI does increase slightly the relative severity and coverage of extreme precipitation anomalies during El Niño conditions compared to the standardized version of the PPI. That the increase manifests itself mainly for El Niño results from the fact that drought is more prevalent in the Tropics during El Niño, and these dry extremes were not adequately accounted for in GD05. Still the values for the "high" category, indicating more severe extremes or greater coverage of extremes, remains similar to what was shown in GD05.[3]

GD05 does not claim that no change in extremes occurs during El Niño or La Niña, only that extremes and related disasters occur in every year. Some ENSO-neutral years may exhibit an overall level of extreme precipitation equivalent to that during a strong El Niño event. Similarly, a particular El Niño may be attended by relatively few cases of extreme precipitation. The difference is that we are better able to predict the precipitation extremes during El Niño and La Niña. The problem is that we must make greater progress in predicting the precipitation extremes in ENSO-neutral conditions. Thus, while ENSO may be the *single* leading cause of extreme precipitation, explaining 15%–20% of precipitation extremes (Dai et al. 1997), 80+% of the variability in precipitation extremes is due to other factors. We must better understand these other factors and work to improve our ability to predict them and their impacts.

Returning to the specific question of C06, "Does the [incorrect] assumption of normality invalidate the conclusions of GD05 regarding the impact of ENSO on precipitation anomalies?" It appears the conclusions may be in the eye of the beholder. We have shown that although a nonparametric treatment of the data leads to better appreciation of the dry anomalies, consistent

[2] As noted in GD05, unexplainable and opposing trends appear in the Global Historical Climatology Network (GHCN) and Climatic Research Unit (CRU) datasets starting around 1995, making both datasets suspect after that time.

[3] The frequency values for ENSO extremes versus neutral conditions are even more similar within the "high" category for global land area (60°S–60°N), particularly in the CRU data.

Table 2. Similar to Table 1a, but using standardized anomalies in rainfall indices. (Taken from Table 4 in GD05.)

	Extreme P′ (PPI)			Extreme P′ (spatial coverage)		
	Low	Med	High	Low	Med	High
El Niño	17% (16%)	68% (77%)	15% (7%)	9% (8%)	75% (71%)	16% (21%)
Neutral	17% (15%)	70% (70%)	13% (15%)	20% (17%)	66% (71%)	14% (12%)
La Niña	10% (10%)	70% (72%)	20% (19%)	9% (11%)	72% (78%)	19% (11%)

with C06, it does not materially change the conclusion of GD05 that overall perturbation to precipitation over land areas is only weakly affected by ENSO extremes. Severe and widespread extreme precipitation can occur in any year, even if its likelihood is somewhat greater during ENSO extremes. In our opinion, the claim that El Niño and La Niña events bring devastating climate anomalies, implying that such is not the case during ENSO-neutral conditions, is a more momentous claim to support. Such an impression has been promulgated by the meteorological community for decades, and although certain regions have high expectation of devastating extremes during El Niño and/or La Niña events, the big picture is more one of redistribution.

Finally, we echo the recommendations originally stated in GD05 and also endorsed by C06, which are to encourage further studies to clarify the relationship between climate extremes and the full range of ENSO conditions. We also strongly agree that such questions can only be properly addressed if the observing networks are maintained and strengthened, especially the ground-based station network, which is not only a fundamental data source but is necessary to calibrate satellite measurements.

Ultimately, the degree to which ENSO affects the global aggregate of hydrometeorological disasters can only be partially resolved in isolation from further analysis of the impacts of climate anomalies (ENSO related or otherwise) on society. In the context of disasters—the particular societal impact examined in GD05—additional research on hazard characterization is needed to refine our understanding of the specific climate conditions associated with climate-related losses, particularly those associated with flooding and drought. The effects of ENSO on the behavior of a more tailored set of hazard indexes would provide a more proximate connection to the particular type of societal impacts in question, and go further toward addressing the larger question of the degree to which ENSO is a blessing or a curse.

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