
# Freshwater flooding versus storm-surge damage

***An analysis of residential, single-family dwelling, tropical cyclone flood insurance claims***

## Summary

The record-breaking losses associated with U.S. landfalling tropical cyclones (TCs) in recent decades, including the catastrophic events of 2017 and 2018, continue to highlight that the U.S. remains highly vulnerable to TC risk. While wind and storm-surge flooding risk are prevalent for landfalling TCs, recent work (including that supported by the Willis Research Network) has highlighted the corresponding significant risk of freshwater flooding stemming from the TC precipitation. Freshwater flooding from TCs has been shown to have substantial socioeconomic impacts, killing hundreds and causing billions of dollars in damage [i,ii,iii,iv,v,vi] affecting large U.S. geographic areas that are not limited to the coast [vi,vii,viii,ix] and potentially having the most severe effects hundreds of kilometers away from the center of circulation [iv,vi,vii,x,xi]. The heavy rainfall and flooding caused by Hurricane Florence (2018), Hurricane Harvey (2017), Hurricane Irma (2017) and Hurricane Matthew (2016) are the latest prominent reminders of this reality.

Despite extensive and persistent flood losses from TCs — freshwater and/or storm surge — the U.S. continues to be inadequately prepared for these flood events, with the lack of residential flood insurance in place being a prime representation of the problem. For example, initial estimates of Hurricane Harvey's total residential flood losses ranged from $25 billion to $37 billion, of which 70% are estimated to be uninsured.[1] One way this substantial flood insurance gap can be addressed is through a better understanding of TC flood risk by the public and the insurance industry, facilitated by data analysis and dissemination. This briefing is based upon research by Tonn and Czajkowski (2018) [xii] and written in collaboration with the Wharton Risk Management and Decision Processes Center at the University of Pennsylvania, a Willis Research Network Partner, to assist in providing a better TC flood risk understanding of both the probability of the flood hazard (freshwater flooding and storm surge) as well as its expected damage impacts in the U.S.

We use actual claim data from the National Flood Insurance Program (NFIP) — the main provider of residential flood insurance in the U.S. — for the full set of all 28 significant U.S. landfalling TC-related flood events[2] (https://www.fema.gov/significant-flood-events) having occurred from 2001 to 2014 [vi]. This allows for an analysis of roughly 465,000 total NFIP TC residential flood claims, which we further split by storm surge and freshwater. While the physical address for each claim is unavailable, location is identified by NFIP community number. Using these data we hope to understand the drivers of TC flood damages, and how impacts can vary according to: 1) geography, 2) individual TC event, 3) the TC flood hazard — storm surge or freshwater, 4) designated NFIP flood risk zone, and 5) flood depth and duration.

This research is timely, as a number of vendor flood catastrophe models have recently been or are in the process of being developed in the U.S., as well as a model being developed by the State of Florida. Validation is necessary if the industry is to accept these models, especially in regard to inland (freshwater) flooding [xiii]. The American Academy of Actuaries

[1] http://www.brinknews.com/legacy-of-harvey-and-irma-turns-on-femas-post-disaster-response/

[2] Hurricane Katrina claims are excluded from the results presented here as not to overshadow results associated with other storms.

Flood Insurance Work Group [xiv] has already raised the question of whether properties subject to either inland or storm-surge flooding should be treated differently — a question tackled through the last couple of years as a Willis Research Network project with Wharton. Consequently, insight into residential property flood vulnerability through realized claim analyses, as we do here, is an important facet of this validation process.

## TC flood loss data

Similar to Czajkowski et al. (2017)[vi], the initial data set for this study includes roughly 465,000 NFIP TC flood claims for single-family properties for the set of all 28 significant U.S. landfalling TC-related flood events having occurred from 2001 to 2014. Our focus is on claims with structural (building) damage, with damage amounts for contents excluded. Only claims with recorded structural damage were included in the analysis, and some claims were removed due to potential errors or inconsistencies. Excluding Hurricane Katrina, roughly 223,000 claims include damage amounts.

## Understanding differences in TC freshwater and storm-surge losses

Claims designated as tidal water overflow represent surge claims in our study. Freshwater claims include claims associated with overflow from a stream, river or lake, and claims associated with accumulation of rainfall or snowmelt. *Figure 1* presents total damage amounts by storm, and it is apparent that the ratio of surge to freshwater damage differs for each storm as does the number of claims associated with surge versus freshwater flooding. For example, Allison in 2001 has a particularly high proportion of freshwater claims (97%), whereas Sandy in 2012 has a high proportion of surge claims (69%). Damage from Allison was due to a high amount of precipitation in Texas, whereas Sandy struck the northeast region and storm surge was a major driver of damage. We find that only four of the TCs studied had more surge than freshwater claims — Alex (67%), Charley (67%), Ophelia (54%) and Sandy (69%).

*Figure 1* provides a summary of number of claims and damage for surge and freshwater claims (dollar losses are adjusted to 2012 values). In the data set, surge claims account for about 32% of the number of claims, and damage and freshwater claims account for 64% of the number of claims. While 32% of the claims are surge-related, surge claims account for 49% of the damage.

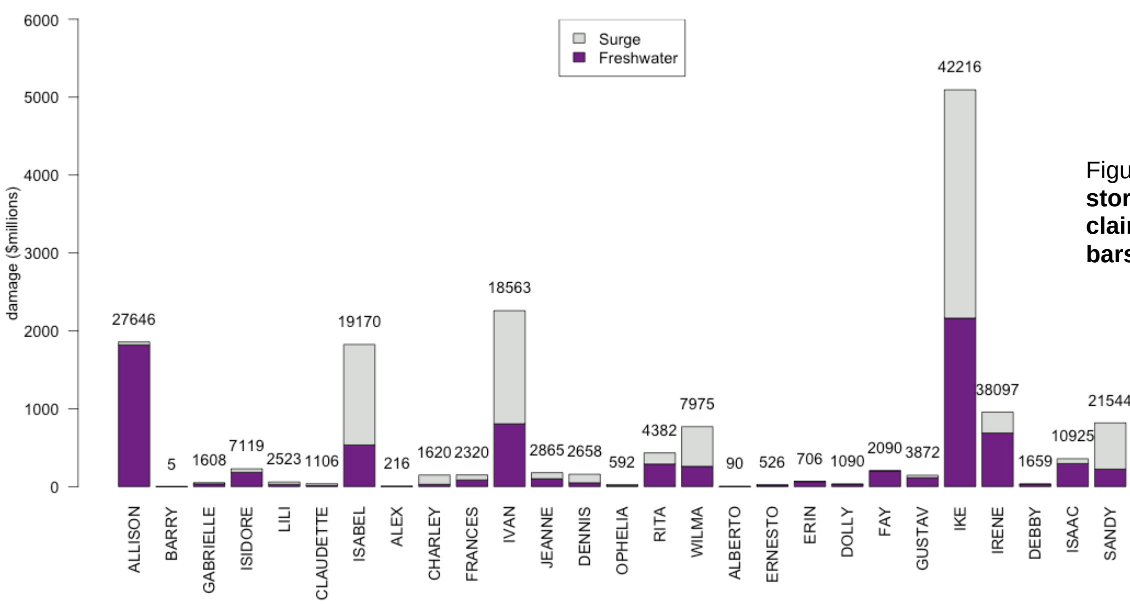


Figure 1. **Total damage by storm (total number of claims shown above bars)**

Table 1: **Summary of paid claims and damage**

| | Number of claims | Total damage | Average damage |
|---|---|---|---|
| Surge | 72,861 (32%) | $7.830B (49%) | $108,972 |
| Freshwater | 151,322 (68%) | $8.089B (51%) | $53,455 |
| Total | 223,183 | $15.919B | $71,330 |
| Difference (p-value) | | | $55,517 (<2.2e-16) |

To further investigate how damage varies from storm to storm, the fraction damaged (ratio of damage to property value) for two TCs is compared in *Figure 2*. Hurricanes Ike and Ivan were chosen for comparison purposes because they each have a relatively significant proportion of both surge and freshwater claims. For both storms, the ratio of damage to property value is the highest in communities that are adjacent to the coast. However, differences exist between the ratios for the two storms, indicating that storm characteristics and geographic considerations are important. The ratio generally declines as distance from the coast increases. This indicates that the nature of the claims — surge versus freshwater — may be significant and at least partially responsible for the higher values of the coastal claims.

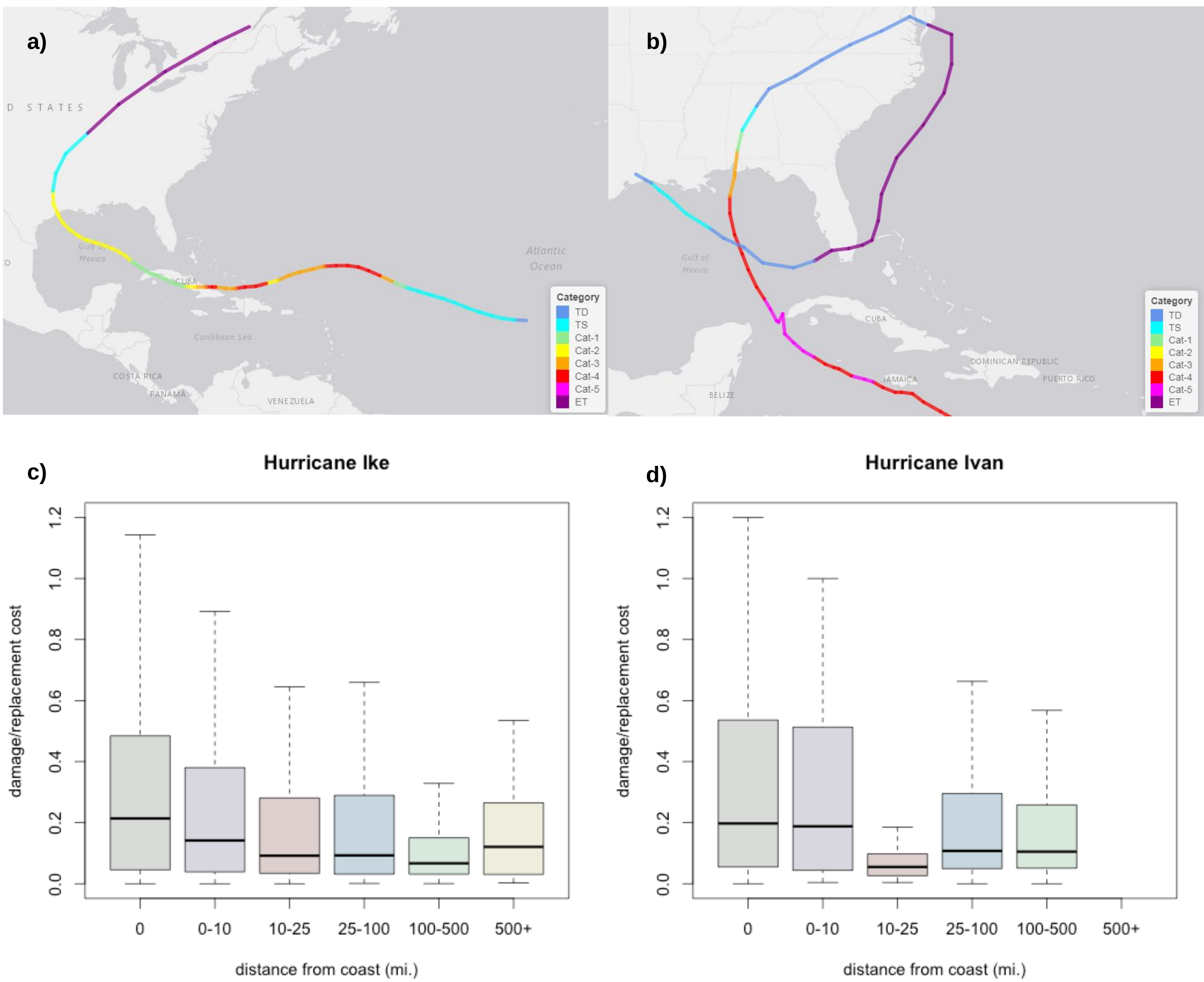


Figure 2**. Hurricanes Ike and Ivan a) track: Hurricane Ike, b) track: Hurricane Ivan, c) box plot distribution of damage ratio by distance from coast: Hurricane Ike,**[1] **d) box plot distribution of damage ratio by distance from coast: Hurricane Ivan**

Flood depth is provided in feet in the NFIP data set, and claims that had a flood depth specified were analyzed to understand how damage and claim amounts relate to depth. We completed a comparison of coastal versus inland depth-damage amounts for freshwater claims accounting for the building exposure value. We define a community as coastal if it is situated within 25 miles from the coast. With a few exceptions, inland and coastal depth-damage amounts are comparable when grouped by depth. We also compared depth-damage for surge claims, separated by V-zone, A-zone and NonSFHA (X-zone), again accounting for the building exposure value.[3] At lower flood depths (less than six feet), the range of NonSFHA depth-damage ratios tends to exceed the range for SFHA ratios. Above the six-foot depth range, V-zone depth-damage values tend to exceed those for A-zone and NonSFHA properties.

*Figures 3 and 4* provide box plots of fraction damaged (damage/structure value) by depth for freshwater and surge claims, respectively. As we are interested in understanding how the claim analysis would corroborate catastrophe flood models, a U.S. Army Corps of Engineers (USACE) [xv] 1.5 story depth-damage curve is overlaid on these plots for comparison. The percent damaged generally increases with depth for both surge and freshwater claims. The exception is in the nine- to 24-foot range for surge claims, potentially a discrepancy due to some improperly recorded flood claim depth. The USACE depth-damage curves align relatively well with both surge and freshwater depth damage amounts up to around the three- to six-foot range. At higher depths of flooding, the USACE curves are at the high end of the range exhibited by this data set. For instance, in the six- to nine-foot depth range USACE values range from 36% to 56%. For this depth range, freshwater depth-damage amounts tend to be in the 6% to 35% range and surge depth-damage amounts tend to be in the 7% to 50% range for our data set.

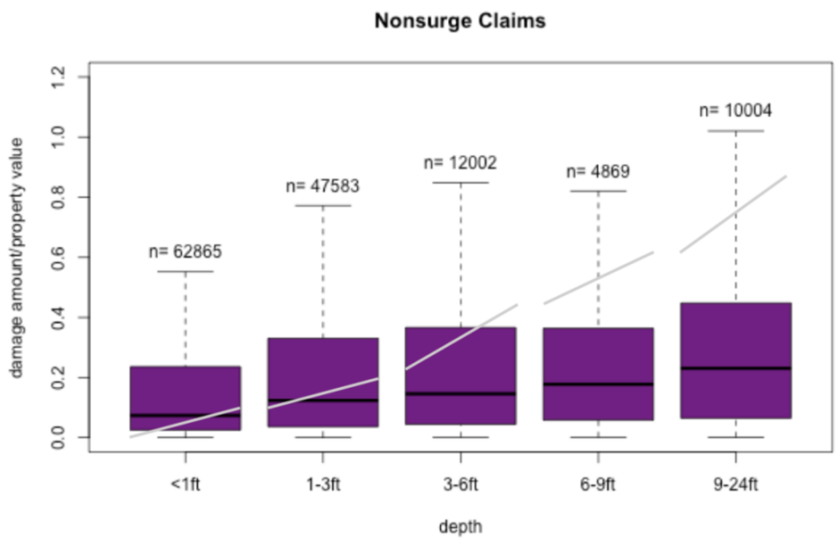


Figure 3. **Depth-damage ratio for freshwater claims with USACE depth-damage curve**

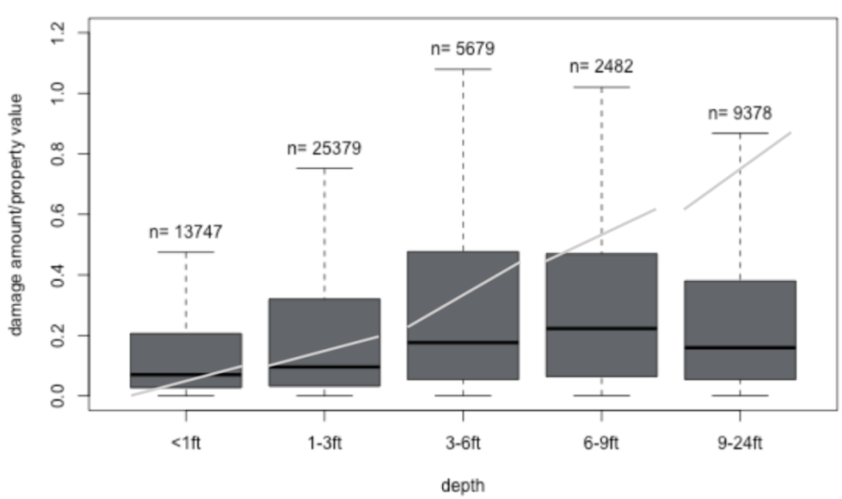


Figure 4. **Depth-damage ratio for surge claims with USACE depth-damage curve**

[3] High flood risk zones, or Special Flood Hazard Areas (SFHAs), are areas that will be inundated by the flood event having a 1% chance (100-year flood) of being equaled or exceeded in any given year (A-zones) with coastal high risk areas also having an additional hazard associated with breaking waves of three feet or more (V-Zones); NonSFHA (X-zone) includes all areas outside of the SFHA.

## Statistical modeling application

In addition to the above results, a series of regression analyses were performed to identify variables that are statistically related to the number of freshwater and surge paid claims. Regressions were performed on both ratio of paid claims to coverage and ratio of damage to replacement cost value. Covariates pertain to both property characteristics such as flood zone and structure type, and community characteristics such as proximity to coast and geographic region. The storm magnitude and depth of flooding are also investigated. We find that flood zone, preFIRM[4] property, elevated structure, multi-story structure and basement were all variables of high significance in the models with the sign of the correlations (positive or negative) as expected. We also find further statistical evidence that flood depth is an important influencer of claim and damage amounts. Specifically, the model results illustrate that claims having a depth of three to six feet are substantially more costly than those having a depth of one to three feet. The relative effect on the claims ratio is 76% for depth of three to six feet versus 40% for depth of one to three feet. For damage ratio, the relative effect is 121% for depth of three to six feet versus 50% for depth of one to three feet. Lastly, we find that a combination of depth and duration (as we have measured it) of flooding are important indicators of freshwater damage amounts.

Mostly notably, the regression models developed in this study can be applied for comparisons of expected depth-damage for different geographies and structures types. For example, following our regression models, *Figure 5* illustrates depth-damage curves for freshwater and surge claims in the Florida and the Gulf Coast region based on single-story, post-FIRM structures without basements located within 25 miles of the coast. This allows for comparison of our model results with depth-damage curves developed by others. USACE [xv] generated depth-damage relationships for Louisiana based on expert opinions, and our Gulf Coast depth-damage values differ substantially from those for both freshwater and saltwater residential flood damage.

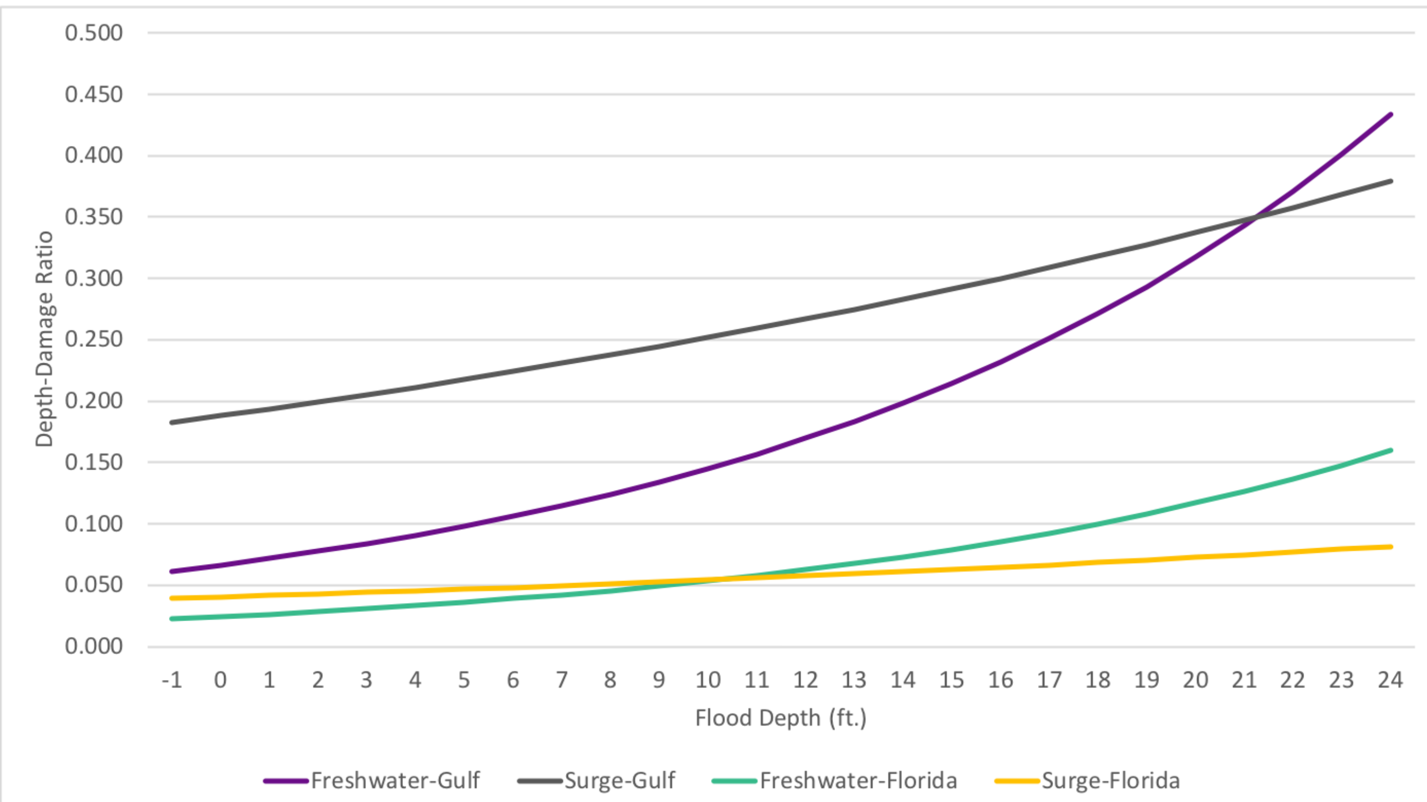


Figure 5. **V-zone depth-damage curves based on regression model, Gulf Coast versus Florida**

[4] preFIRM refers to a property constructed prior to the authorization of FEMA's NFIP and Flood Insurance Rate Map (FIRM) for a community.

## Concluding comments

While TCs are generally associated with storm-surge flooding, recent storms have illustrated the significance of freshwater TC flood damage. Through separate analysis of freshwater and storm-surge TC claims, our work illustrates key differences between the number of claims and damage for freshwater and surge claims as well as differences associated with flood zone, geography, TC event, and flood depth and duration.

The findings provide important insights for flood loss and insurance considerations as well as for the mitigation and management of TC flood risk. This detailed claim information and analysis should be useful for verification of new and existing inland flood catastrophe model loss amounts, as well as provide a better understanding of claim characteristics for underwriting, accumulation and risk-financing purpose.

For more information on how Willis Re can help you manage your risk associated with tropical cyclone flood damage, please contact your client advocate or Prasad Gunturi.

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