Climate change is already influencing real estate markets, with properties exposed to sea level rise in the United States selling at a 7 percent discount to those with less exposure.

Market intelligence provider Four Twenty Seven and real estate technology company GeoPhy have partnered to assess the exposure to the physical impacts of climate change of 73,500 properties owned by 321 listed Real Estate Investment Trusts (REITs).

35 percent of REITs properties are exposed to climate hazards. Of these, 17 percent of properties are exposed to inland flood risk, 6 percent to sea level rise and coastal floods, and 12 percent exposed to hurricanes or typhoons.

U.S. markets most exposed to sea level rise include New York, San Francisco, Miami, Fort Lauderdale, and Boston. The high-value REITs most exposed to sea level rise in the U.S. are Vornado Realty Trust and Equity Residential.

Globally, REITs concentrated in Hong Kong and Singapore display the highest exposure to rising seas. Sun Hung Kai Properties, worth $56 billion, has over a quarter of its properties exposed to coastal flooding.

37 Japanese REITs have their entire portfolio exposed to the highest risk for typhoon globally, representing $264.5 billion at risk in properties in Tokyo and other Japanese cities.
INTRODUCTION

Climate events, including storms and floods, pose a significant risk to buildings, whether commercial or residential. The recent sequence of superstorms and subsequent flooding events in major U.S. cities serves as a tangible reminder. Hurricane Florence, which made landfall in North Carolina in September 2018, affected properties owned by 94 U.S. REITs, including 5,545 assets (545,000,000 sq.ft.), as well as 2,900 properties and loans in commercial mortgage-backed securities (CMBS).1 Although only a portion of these properties experienced direct damage, the impacts from these types of events can be widespread and costly for many. Estimated economic losses from Hurricane Florence are over $10 billion. Due to low insurance penetration, the majority of flood damage is likely to be uninsured.2 Beyond storms and flooding, climate risks also include cold spells, heat waves, drought, and periods of extended precipitation. These weather events affect properties that are dependent on water supply, drainage and sewage infrastructure, along with the functioning of temperature controls and wastewater treatment plants. Such adverse conditions, in turn, impact utility costs, operating expenses, market values, and the protection of public health. Properties with high water and energy consumption such as manufacturing facilities, hospitals and data centers may suffer impacts to their operating costs and revenues.

Research by the World Meteorological Organization has concluded that 80 percent of natural disasters between 2005 and 2015 were in some way climate-related. A recent analysis of 59 studies in English-language scientific journals published between 2016 and 2017 found that 70 percent of studies concluded that climate change has increased the risk of a given extreme event, such as heat, drought, rainfall, wildfires, and storms.3 As climate change continues to affect buildings and markets globally, the value of real estate will increasingly reflect these risks.

DOES CLIMATE AFFECT REAL ESTATE PRICES?

Evidence on the impact of climate risks on real estate returns is slowly starting to emerge. A high-profile study by the University of Colorado at Boulder and Pennsylvania State University, published by the Journal of Financial Economics,4 found that properties exposed to sea level rise are now selling at a 7 percent discount relative to comparable but less-exposed properties across the nation.5,6 Buyer behavior reflects the expense of frequent flooding and the threat of lower resale values in the future due to sea level rise. The experience in Miami is an early example of the vulnerability of housing markets in

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ARE YOUR REIT INVESTMENTS AT RISK?

Four Twenty Seven and GeoPhy have partnered to bring together risk-driven analytics on physical climate risk exposure with in-depth structured data on the global real estate market. The combination of cutting-edge datasets and models allows for highly granular observations of the impacts of climate change on the real estate investment market.

Four Twenty Seven, a market intelligence firm specialized in the economic risk of climate change, has developed a model that leverages global climate data to provide asset-level risk assessments and score real assets, infrastructure assets and listed instruments on their exposure to climate change impacts. GeoPhy is a technology company in the real estate space, providing an automated valuation platform for the commercial real estate sector. Using data science and supervised machine learning to optimize the unprecedented volume of data now available to the sector, GeoPhy exposes decisive features that drive real estate values. See Methodology section (p.12) for more details on the underlying data and methodology.

Four Twenty Seven applied its data and models to GeoPhy’s data on listed real estate investment trusts’ holdings globally, creating the first in-kind global, scientific assessment of REITs’ exposure to climate risk. This white paper highlights key findings from the analysis of 73,694 properties owned by 321 listed REITs as of Q2 2018. The first section presents high level findings and key measures of exposure to risks. We then provide a detailed analysis on three major risks: extreme rainfall and inland floods, sea level rise and coastal floods, and cyclones, hurricanes and typhoons.

UNDERSTANDING EXPOSURE TO CLIMATE RISKS

Four Twenty Seven uses two different thresholds to characterize the level of risk for a property:

**Exposed Properties**

“Exposed” sites are properties that have a high probability of experiencing medium to high impact events – this typically translates as a score of 50 or more out of 100.

- For floods, properties that score 50 are sites that have experienced at least some flooding at a return interval of at least 1:500 (noting that Hurricanes Harvey, Florence and Irma were all 1:1000 events). Any score higher than 50 indicates greater frequency and/or extent (depth) of flooding.
- For sea level rise, properties that score at 50 are generally coastal sites that are below <10m in elevation and that will experience disruptions due to floods to the surroundings. Any site with a score of 60 and up is already experiencing flooding or will likely be flooding by 2040.
- For cyclones, properties that score 50 or higher have experienced multiple Category 3 and up hurricanes (or recurring instances of tropical storms) in the past 35 years and are likely to

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experience more intense cyclones (tropical storms, hurricanes or typhoons) in the future.

- Properties are considered exposed to water stress or heat stress if they fall in the 5 percent most exposed facilities in Four Twenty Seven’s global universe of corporate facilities. We focus on the most extreme cases because extreme heat or drought do not inflict direct damages to a building, but in extreme cases could drive down local real market prices and property valuations.

In our analysis of REITs assets globally, we found that 17 percent of properties were exposed to flood risk, 6 percent were exposed to sea level rise, and 12 percent were exposed to cyclones. Figure 1 provides a view of REITs’ exposure to floods globally, highlighting urban areas with the greatest concentration of properties exposed to floods.

![Figure 1. Percent of properties exposed to flood by urban area.](image)

This map represents the geographic repartition of the 73,694 sites scored by GeoPhy and Four Twenty Seven. The size of the dots represents the number of sites in a city or Metropolitan Area, and the color signals the percentage of these sites exposed to flood risk, with red representing the highest percentage and dark green representing the lowest. Note that cities with less than 25 sites are not represented on the map.

**Red Flag Properties**

We provide an additional measure of risk for facilities at high risk of high impact events: Red Flags. Facilities with a Red Flag fall in the 5 percent most exposed properties of all facilities scored by Four Twenty Seven’s global database of over 1,100,000 corporate facilities. In our assessment of REITs, 4,355 properties were tagged with a Red Flag due to extreme flood risk, 4,409 due to extreme hurricane or typhoon risk, 1,413 due to extreme sea level rise risk, and 1,867 due to extreme water stress. A small subset of facilities, 1138 properties globally, received two or more Red Flags, for example due to compounded exposure to cyclones and sea level rise or floods.

**REITs Climate Risk Scores**

REITs are scored based on the average of the exposure of all the sites they hold in their portfolio, by climate hazard. We also provide an average Climate Risk Score, which is the weighted average of the scores for the different hazards.

To avoid averaging effects that might hide extreme risk (for example, a REIT might hold a mix of properties with very high and very low exposure to a hazard), we also provide the percentage of “exposed” properties that REIT holds. Figure 2 illustrates our findings for the 321 REITs by value and risk exposure.
We find that the most exposed REITs are primarily geographically concentrated in Asia - Japan, Hong Kong and Singapore in particular. Champion REIT stands out due to the geographic concentration of its properties in Hong Kong, and the city’s high exposure to flood, sea level rise and typhoons. Sun Hung Kai Properties, Sumitomo Realty & Development and Mitsui Fudosan also rise to the top as the most exposed large REITs with high exposure in their portfolio.

In the U.S., REITs with a large number of coastal properties such as Equity Residential also exhibit high risk portfolios, with a third of their portfolio exposed to climate risk.
Floods

Floods not associated with hurricanes caused 30 billion dollars damage globally in 2017. Climate change will increase flood risk by amplifying the intensity and variability of rain storms. As temperatures warm, the air can hold more moisture, which leads to the potential for more intense precipitation conditions.

Floods can have both direct and indirect impacts on buildings, as they can damage property and nearby infrastructure and disrupt operations. Impacts from both fluvial and pluvial floods can include higher costs associated with maintenance and repair of buildings, higher insurance premiums, and loss of revenue from business disruptions.

The cost of floods was illustrated by the lasting damage inflicted by Hurricane Harvey in Houston. Harvey brought over 20 inches of rain to the region, with some areas experiencing over 50 inches. With $125 billion in damage overall, 204,000 homes and apartment buildings were damaged, particularly affecting the residential market.

One of the REITs included in this analysis, American Homes 4 Rent, a residential REIT, experienced $20 million hurricane-related losses.

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charges in 2017 as a result of Hurricanes Harvey and Irma. In all over 3,500 properties were affected across Houston, Texas, Florida and other Southeastern states. Figure 4 shows the American Homes 4 Rent’s properties in Houston, with a large number of sites scored as highly exposed to flood risk (orange and red dots).

After insurance payments worth $11 million, the company was still left with a tab of $10.1 million in repairs, upgrades and lost revenues. The company was still able to report strong third quarter results in 2017 despite these impacts, but recurring events across the company’s markets and potential changes in insurance coverage could have a negative effect on the REIT’s financials over time.

Four Twenty Seven’s flood indicator displayed on Figure 4 measures the severity and frequency of historical pluvial and fluvial floods, the frequency of future heavy rainfall events, and the intensity of prolonged periods of heavy rainfall, leveraging data from global climate models and modeling firm Fathom. Flood risk is assessed with a precision of 30x30m.

**Sea Level Rise**

Climate change is causing sea levels to rise because of rising temperature and ice melt. Over the long term, sea level rise threatens to reshape our coastlines and presents a major threat to numerous coastal properties. Today, rising seas already affect real estate by contributing to increased “nuisance” flooding and king tide coastal flooding in low lying coastal areas such as Miami, Florida. Sea level rise also exacerbates the flood risk from storm surges, as experienced with Hurricane Sandy, Hurricane Florence, and Typhoon Mangkhut. Rising seas threaten to turn historically rare damaging flood events into more frequent occurrences, leading to higher maintenance and repair costs for infrastructure.

Sea levels will continue to rise globally, posing an increasing threat to coastal infrastructure in the coming years and decades. As noted earlier, anticipation of these impacts already influences real estate markets, and will increasingly continue to do so.

Four Twenty Seven’s sea level rise indicator reflects the absolute and relative increase in the frequency of coastal floods, measured at the parcel level. It incorporates local flood risk statistics, as well as local median sea level rise projections under a business as usual carbon emissions scenario.

In the United States, key markets at risk include the San Francisco Bay Area, the New York City metro area, and Miami and Fort Lauderdale in Florida, as shown in Figure 6.

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Among high-value U.S. REITs, Vornado Realty Trust stands out, with 76 out of 78 properties exposed to sea level rise, primarily concentrated in the New York area. While Vornado experienced only minor damage from Superstorm Sandy, it has since pursued investments in flood protection.

Equity Residential is the high-value REIT second-most exposed to sea level rise in the United States. The REIT invested exclusively in coastal properties and has properties exposed to sea level rise in all of its major markets, including New York, San Francisco and Washington, D.C. While Equity Residential has made a number of commitments related to sustainability in their portfolio and recognizes potential climate risk in annual reports, the company has not made strategic investments to help diversify portfolio exposure to climate risk.

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Table 1. Top Ten Most Exposed High-Value REITs to Sea Level Rise

<table>
<thead>
<tr>
<th>REIT</th>
<th>Enterprise Value (USD)</th>
<th>Average Sea Level Rise Risk Score</th>
<th>No. of Red Flags</th>
<th>No. of Properties exposed</th>
<th>% Portfolio Exposed</th>
<th>Key Markets Exposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>New World Development</td>
<td>$26.9B</td>
<td>49</td>
<td>5</td>
<td>10</td>
<td>38%</td>
<td>Hong Kong</td>
</tr>
<tr>
<td>Sun Hung Kai Properties</td>
<td>$56.6B</td>
<td>41</td>
<td>8</td>
<td>20</td>
<td>28%</td>
<td>Hong Kong</td>
</tr>
<tr>
<td>Vornado Realty Trust</td>
<td>$25.8B</td>
<td>41</td>
<td>1</td>
<td>12</td>
<td>15%</td>
<td>New York</td>
</tr>
<tr>
<td>Henderson Land Development</td>
<td>$34.2B</td>
<td>35</td>
<td>3</td>
<td>9</td>
<td>19%</td>
<td>Hong Kong</td>
</tr>
<tr>
<td>Swire Properties</td>
<td>$23.7B</td>
<td>31</td>
<td>2</td>
<td>4</td>
<td>8%</td>
<td>Hong Kong and Miami</td>
</tr>
<tr>
<td>Cheung Kong Property</td>
<td>$36.9B</td>
<td>30</td>
<td>11</td>
<td>22</td>
<td>22%</td>
<td>Hong Kong and Singapore</td>
</tr>
<tr>
<td>Sumitomo Realty &amp; Development</td>
<td>$47.7B</td>
<td>29</td>
<td>7</td>
<td>28</td>
<td>14%</td>
<td>Tokyo</td>
</tr>
<tr>
<td>Mitsui Fudosan</td>
<td>$48.4B</td>
<td>27</td>
<td>16</td>
<td>54</td>
<td>21%</td>
<td>Tokyo</td>
</tr>
<tr>
<td>Mitsubishi Estate</td>
<td>$42.3B</td>
<td>25</td>
<td>11</td>
<td>24</td>
<td>12%</td>
<td>Tokyo, New York</td>
</tr>
<tr>
<td>Equity Residential</td>
<td>$32.9B</td>
<td>25</td>
<td>14</td>
<td>35</td>
<td>13%</td>
<td>New York, San Francisco and Washington D.C.</td>
</tr>
</tbody>
</table>

Figure 8. Sea Level Rise Exposure in Hong Kong. Dots represent properties and the color of each dot represents the sea level rise score, with red representing the highest risk and dark green representing the lowest risk.

High value REITs are considered the top 25 REITS by Enterprise Value. For the dataset used in this analysis, these include REITs with over $22,400 million in Enterprise Value.
Internationally, Singapore, Hong Kong, and Malmö, Sweden are some of the key markets with high exposure to sea level rise. Numerous small to mid-sized cities, such as Morehead City, North Carolina or, Hull and Grimsby in the United Kingdom are also at high risk. Table 1 shows the Top Ten REITs Most Exposed to sea level rise (among REITs above $25 bn in Enterprise Value).

The REIT most exposed to sea level rise in our coverage universe is Sun Hung Kai Properties, which has $56 billion\(^\text{18}\) worth of assets and is largely concentrated in Hong Kong. Among smaller REITs, several have over 40 percent of their portfolios exposed to sea level rise, including Mapletree Commercial Trust, Japan Logistics Fund, Alexander's, and The Wharf (Holdings).

### Hurricanes and Typhoons

Cyclones are a major source of weather-related damage globally. Hurricanes Harvey, Irma, and Maria caused $220 billion economic damage in 2017. More recently, in September 2018, Hurricane Florence caused an estimated $10 billion in forecast economic losses in the Carolinas, with the majority of the flood damage being uninsured. In the same month, Super Typhoon Mangkhut struck Japan and the Pearl River Delta, including Hong Kong, one of the largest real estate markets in the world.

Four Twenty Seven’s cyclone (the generic term for hurricanes, typhoons and tropical storms) indicator is derived from a measure of the cumulative wind velocity from recorded cyclones experienced in any given location between 1980 and 2016. This cumulative measure reflects both the severity of storms with the highest maximum winds, but also the frequency with which an area is subjected to severe storms.

The Japanese real estate market is particularly exposed to typhoons. Japan has experienced 9 major typhoons as of October 2018, including Typhoon Jebi which hit Japan with 100 mph winds, leading to widespread flooding and damages, billions of dollars in economic losses, and over 480,000 filed insurance claims.\(^\text{20}\) This high exposure is reflected in the risk assessment of Japanese real estate properties. Of the 4,409 properties with a red flag for hurricanes and typhoons, 84 percent are located in Japan.

Tokyo features the most property value at risk from typhoons in the world, with 911 Red Flag properties. Figure 10 highlights REITs with an average cyclone score of 80 or more, and 60% or more of their portfolio exposed to cyclones. Japanese REITs are overrepresented in this sample, with 37 of them having a portfolio score of 90 or above or having 90% of their properties ranked as Red Flags, with a cumulative value at risk of $264.5 billion.

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\(^{18}\)FactSet: https://www.factset.com/


Figure 10. REITs most exposed to hurricanes and typhoons. Each dot represents a REIT. The x-axis shows a REIT’s Enterprise Value (Factset, September 2018) and the y-axis shows the REIT’s Cyclone Risk Score. The color of the dots denotes the percent of properties with red flags for cyclone risk. Red dots indicate REITs that hold sites where half or more of the sites are exposed to cyclones. The size of the dots represent the REITs’ value.

CONCLUSION

The impacts of climate change are already affecting real estate markets, but the widespread, long-term consequences for economies, economic growth and equity are just starting to emerge. For institutional REIT investors, but also for investors in private equity real estate equity funds and direct investors in real estate, understanding exposure to any form of risk is paramount. The duty of investors towards clients and trustees is the foundation of the capital market. Stewards of capital should carefully assess current and future risks.

Four Twenty Seven’s local climate risk exposure risk scores and GeoPhy’s robust real estate investment data bring science-driven analytics to support efforts to understand REIT-level financial vulnerability to climate change and can be leveraged as a starting point for more robustly informed investing. By coupling an understanding of physical climate risk exposure with a knowledge of their investment interests, investors can play a key role in the development of more resilient and thriving real estate investment economy.
Mapping REITs Properties
GeoPhy tracks the portfolio composition of every major listed property company in the world. At the REIT/portfolio level, GeoPhy has collected data on the individual assets in portfolios of listed property companies, using data sourced from tens of thousands of direct feeds from REITs, as well as feeds from LPs investing in REITs. The asset-portfolio match has a history of 5 years, is current as of Q2 2018, and is performed quarterly. By combining that dataset of over 600 companies with its unique enrichment layers, GeoPhy can create portfolio benchmarking on metrics such as sustainability, portfolio quality and portfolio risk.

GeoPhy maps three types of assets for each equity REIT:
- REITs typically own assets, either outright or partially. GeoPhy tracks ownership stakes in each of the assets that are on the REIT balance sheet;
- In some cases, REITs manage assets for wholesale funds/separate accounts operated in-house. They may or may not have an equity stake in these assets. GeoPhy tracks the assets that REITs manage, even if they don’t fully own those assets;
- REITs can have equity stakes in other REITs. GeoPhy tracks ownership stakes in other REITs, and for those REITs map the assets underlying the portfolio.

For the Four Twenty Seven/GeoPhy REIT Climate Risk data collection effort, we consider all forms of ownership and management by REITs, thus including indirectly owned assets, as well as assets managed, but not owned by REITs. This scope aligns with the portfolio reporting of most REITs.

Modeling climate impacts at the property-level
Four Twenty Seven’s models provide detailed, contextualized projections of climate impacts for key climate risk hazards: floods from extreme precipitation, exposure to hurricane-force winds, sea level rise, water stress and heat stress for each site. For floods, sea level rise and cyclones, the analysis is site-specific (parcel level). For water scarcity, the analysis focuses on the most specific and relevant geographic area, i.e. water basin. Each dimension of risk is scored on a scale of 0 to 100. Scores are normalized so companies’ or infrastructure sites’ climate risk can be compared across diverse portfolios.

<table>
<thead>
<tr>
<th>Climate Hazard</th>
<th>Description</th>
<th>Potential Business Impacts</th>
<th>Spatial scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Stress</td>
<td>Increase in temperature</td>
<td>Increased energy costs&lt;br&gt;Heightened risk of brownouts/power outages&lt;br&gt;Stress on human health/labor force</td>
<td>25x25km</td>
</tr>
<tr>
<td>Water Stress</td>
<td>Change in water supply and demand</td>
<td>Reduced water supply&lt;br&gt;Increased water costs&lt;br&gt;Social license to operate/reputation</td>
<td>watershed</td>
</tr>
<tr>
<td>Floods</td>
<td>Change in rainfall conditions and size and frequency of possible floods</td>
<td>Property and building damage&lt;br&gt;Compromised infrastructure&lt;br&gt;Business interruptions</td>
<td>30x30m</td>
</tr>
<tr>
<td>Cyclones, Hurricanes, Typhoons</td>
<td>Exposure to past cyclones</td>
<td>Severe property damage&lt;br&gt;Permanent loss of property value&lt;br&gt;Relocation costs</td>
<td>90x90m</td>
</tr>
<tr>
<td>Sea level rise</td>
<td>Heightened storm surge, augmented by sea level rise</td>
<td>Nuisance floods, property damage&lt;br&gt;Permanent loss of property value&lt;br&gt;Relocation costs</td>
<td>90x90m</td>
</tr>
</tbody>
</table>

Table 2. Four Twenty Seven’s Climate Risk Indicators.
Four Twenty Seven (427mt.com) is the leading provider of market intelligence on the impacts of climate change for financial markets. We tackle physical risk head on by identifying the locations of corporate production and retail sites around the world and their vulnerability to climate change hazards such as sea level rise, droughts, floods and tropical storms, which pose an immediate threat to investment portfolios.

Four Twenty Seven’s ever-growing database now includes close to one million corporate sites and covers over 2000 publicly-traded companies. We offer subscription products and advisory services to access this unique dataset. Options include data licenses, an interactive analytics platform, and company scorecards, as well as reporting services, scenario analysis, and real asset portfolio risk assessments.

Four Twenty Seven has won multiple awards for its innovative work on climate risk and resilience and our work has been featured by Bloomberg, the Financial Times and the UNFCCC. Four Twenty Seven was founded in 2012 and is headquartered in Berkeley, California with offices in Washington, DC and Paris, France.

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