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Research article

Sea level rise in Los Santos and Los Angeles: a comparative flood analysis using Grand Theft Auto V

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Abstract. We present the first quantitative GIS-based flood inundation analysis using terrain data reproduced from a commercial video game, applied to the fictional city of Los Santos from Grand Theft Auto V (GTA V) under two contrasting IPCC Fifth Assessment Report (AR5) Representative Concentration Pathway (RCP) scenarios (RCP 2.6, strong mitigation, and RCP 8.5, high-emission baseline) combined with historical storm surge records from the Los Angeles tide gauge, across three time horizons (2100, 2300, and 2500). Los Santos serves as an ideal case study because it faithfully replicates Los Angeles (LA), enabling direct comparison of simulated flood outcomes in the game world with published scientific vulnerability analyses for LA. Results indicate that Los Santos is modelled with sufficient geomorphological detail for projected flooding patterns to closely resemble those identified for Los Angeles, including the spatial sequence of inundation across the marina district, the Pacific Palisades coastline, and the port. Under the RCP 8.5 scenario with storm surges, combined sea levels are projected to reach 5.18 m by 2300, with the model showing 5.1 % of the mapped land area inundated; for a 2500 scenario with projected sea levels of 8.22 m this increases to 6.5 % modelled inundation, which places the port, wastewater infrastructure, and coastal energy facilities at risk. Under the RCP 2.6 mitigation scenario the model shows 2.2 % of land area inundated at 2300 with storm surge, with no major infrastructure affected. Simulations driven instead by IPCC AR6 projections for the Los Angeles tide gauge, which extend to 2150, give modelled 2100 inundation 24 % to 40 % lower without storm surge, but only 7 % to 8 % lower once the surge is included, so the comparison with Los Angeles is insensitive to the choice of assessment report. The familiarity of the Los Santos environment offers an affective engagement with climate change impacts that conventional visualisation struggles to achieve, but the applications we can responsibly recommend are non-formal rather than classroom-based, and require the limitations of static inundation modelling to be communicated alongside the maps.

> "I don't mind dyin', you feel me? But I just want to die over somethin' that matters, homie." – Franklin Clinton, one of the three main protagonists of Grand Theft Auto V

1 Introduction

Sea level rise is among the most consequential and spatially tangible consequences of anthropogenic climate change (IPCC, 2021). Its impacts on coastal cities, where the majority of the global population lives and where economic and cultural assets are concentrated, represent one of the defining challenges of the coming centuries. Yet communicating the spatial reality of these impacts to broad audiences remains difficult: abstract projections of centimetres or metres of rise rarely convey the human meaning of flooding in a specific neighbourhood or the submergence of a familiar landmark.

At the same time, video games have become one of the dominant cultural media of the twenty-first century, with more than 3.4 billion active players worldwide in 2024 (Newzoo, 2024). The growing graphical and topographic realism of modern open-world games has opened a new avenue for geoscience communication: if the virtual landscapes players inhabit faithfully represent physical environments, those environments can become pedagogical objects in their own right (Hut et al., 2019; McGowan and Alcott, 2022). Previous work on game-based approaches in geoscience has examined whether players can distinguish realistic from unrealistic landscapes (Hut et al., 2019), and has catalogued the geological features of game worlds modelled on real locations such as Hokkaido, Japan (McGowan and Alcott, 2022), and has surveyed the portrayal of volcanoes across commercial games (McGowan and Scarlett, 2021). A common conclusion is that educational value scales with geomorphological fidelity.

Grand Theft Auto V (GTA V), developed by Rockstar Games and released in 2013, has sold more than 225 million copies, making it the second best-selling video game of all time (Take-Two Interactive, 2025) and is set in Los Santos, a fictional recreation of Los Angeles (LA) and its surroundings that is widely praised for its topographic and urban detail. The development team undertook extensive location scouting, and the resulting cityscape reproduces iconic LA landmarks, neighbourhoods, and coastal morphology with a fidelity that has been noted in science communication contexts (Williams, 2019). Unlike game worlds studied in the previous geo-gaming literature, GTA V's Los Santos has a specific, well-documented real-world counterpart with an extensive scientific literature on its coastal vulnerability (Grifman et al., 2013; Moffatt & Nichol, 2018). This creates a unique opportunity: flood simulations performed on the Los Santos terrain can be directly compared against published vulnerability analyses for Los Angeles, providing an empirical test of the game's geomorphological realism.

This paper addresses two questions. First, how does the Los Santos game terrain perform as a substrate for GIS-based flood inundation modelling under IPCC sea level rise scenarios? Second, do the resulting flood patterns correspond spatially to vulnerability analyses conducted for the real city of Los Angeles? We describe the simulation methodology, present results across four scenario and storm-surge combinations at three time horizons, validate the output against the LA literature, and discuss the scientific implications together with the communication applications the approach can responsibly support. To our knowledge, this is the first study to perform a quantitative GIS-based climate impact simulation using terrain data reproduced from a commercial video game, and to validate the results against peer-reviewed analyses of the real-world location that inspired it. The study derives from the first author's master's thesis (Nörenberg, 2020).

2 Study area

Los Santos is the primary setting of GTA V and occupies a coastal island of approximately 44.4 km^2 of land area within the game world (total map area 74.3 km^2 including sea). The city's design was explicitly modelled on Los Angeles, with Rockstar's team reproducing iconic topographic and urban features across multiple scales. Major districts have widely recognised real-world counterparts, documented in the GTA community literature (GTA Wiki, 2020a–e) and verified independently in this study through in-game measurement and visual inspection: Vespucci corresponds to Venice Beach, including the marina canal system; Chumash to Malibu; Del Perro to Pacific Palisades; the Port of South Los Santos to the Port of Los Angeles; and Mount Chiliad (in-game elevation 798 m) broadly to the mountainous terrain north of the LA basin. We note that the GTA Wiki, like much knowledge about commercial video game environments, is a community-maintained resource without formal editorial oversight. The district correspondences it documents are, however, consistent with our own in-game observations and with the visual and topographic comparisons performed in Sect. 5.2; the independent distance and elevation calibrations described in Sect. 3 serve as an additional empirical cross-check of the game terrain's fidelity to reality.

Los Angeles itself is characterised by a low-lying alluvial coastal plain backed by the Santa Monica Mountains, with major flood-prone zones at Venice, Santa Monica, and the harbour district of San Pedro. Historical tide gauge records at the Los Angeles station (NOAA station 9410660) document a long sea level record against which storm surge events can be characterised. Published sea level rise vulnerability analyses (Grifman et al., 2013; Moffatt & Nichol, 2018) provide the comparative baseline for this study.

3 Data and methods

3.1 Terrain data acquisition and processing

Raw terrain data from Rockstar Games were not available; a formal request to the developer was declined on grounds of publishing rights. Community-derived three-dimensional map data published by user "Somnit" on Sketchfab (Somnit, 2020) were identified as the highest-quality publicly available terrain dataset for GTA V, featuring continuous elevation information at a spatial resolution sufficient for inundation analysis. The dataset was downloaded in .fbx format (a standard 3D interchange format) and converted to a .3ds multipatch file using the ASPOSE online converter (ASPOSE, 2020). The .3ds file was imported into ArcMap and converted to a raster using the ArcToolbox Conversion Tool.

The raster was georeferenced against a satellite-view image of the GTA V environment published by Zier (2013) using 11 ground control points (Fig. 2a) and a first-order polynomial transformation. The native cell size of the raster at



Figure 1. Overview map of Los Santos (Grand Theft Auto V) with key locations referenced in this study. District names are given with their Los Angeles counterparts in parentheses: Vespucci (Venice Beach), Chumash (Malibu), Del Perro Beach (Pacific Palisades), Port of South Los Santos (Port of Los Angeles), Los Santos International Airport (LAX), and Mount Chiliad (798 m, highest point in the game map). Base map: community reproduction of in-game terrain from Grand Theft Auto V, © Rockstar Games; reproduced for scholarly comment and not covered by the CC BY licence of this article.

this stage was approximately 2 m (derived from the resolution of the source .fbx mesh), so a residual error held below 1 pixel corresponds to a positional uncertainty of the order of 2 m. Note that the ASPOSE web converter used for the .fbx → .3ds conversion step is a commercial service; an equivalent result can be obtained using the open-source Blender software (https://blender.org, last access: 3 November 2026) with the standard FBX import and export pipeline, ensuring full reproducibility. The terrain dataset features a continuous transition between subaerial and subaqueous environments with no discrete shoreline encoded. To establish a mean sea level (MSL) datum, 31 shoreline points were identified on the satellite image at locations satisfying two criteria: (i) unambiguous cartographic position, and (ii) presence of a beach rather than a cliff. Each point was verified in-game by helicopter overflight. The mean pixel value at these 31

points was −333.25 (SD 0.36; Fig. 2b), and this value was adopted as the MSL shoreline datum.

The highest point in the game, Mount Chiliad (798 m; GTA Wiki, 2020a), was used to calibrate the pixel-to-metre conversion, which was applied via the ArcToolbox Raster Calculator to produce a metric digital elevation model (DEM) with a cell size of 1.05 m, the value implied by the independent area calibration described in Sect. 3.2.

3.2 Area calculation and in-game distance calibration

Online sources report highly inconsistent total map areas for GTA V, ranging from under 40 km^2 to over 100 km^2 depending on the source, making it impossible to rely on published figures. An independent distance calibration was therefore performed using the in-game navigation system, which reports distances to user-defined waypoints in real time. A series of features with clearly identifiable start and end points were selected: the main runway at Los Santos International Airport, two bridge spans with straight alignments, and three straight road segments with unambiguous termini. For each feature, a waypoint was placed at the far end and the distance was recorded as the vehicle approached at low speed; the same vehicle (a standard sedan) was used for all measurements to eliminate any vehicle-scale effects on the navigation readout. These in-game distances were then matched to measurements of the same features in ArcGIS. The ratio between each pair of measurements was computed, and the mean across all six features yielded a conversion factor of 276 m of real-world in-game distance per 1 cm measured on the ArcGIS map at 1 : 1 scale. The standard deviation of the conversion factor across the six features was 11 m cm^{-1} (4 % of the mean), indicating that the GTA V map uses a consistent internal scale. Applying this conversion factor, the total mapped area (land and sea combined) was determined as 74.3 km^2, of which land constitutes 59.7 % (44.4 km^2). All reported flooded areas are expressed as a percentage of this land area.

An artefact was identified in the Alamo-Sea inland lake, where coarse polygon-like representation of lake bathymetry produced spurious flooding signals in deeper basins that are already beneath the lake surface. A polygon mask matching the lake boundary was created and applied to exclude these pixels from all flood area calculations.

3.3 Sea level rise scenarios

Sea level rise projections were taken from the IPCC Fifth Assessment Report (AR5; IPCC, 2013), using two contrasting Representative Concentration Pathways. RCP 2.6 represents a strong mitigation scenario targeting a radiative forcing of 2.6 W m^{-2} by 2100, consistent with limiting warming to approximately 2 °C (van Vuuren et al., 2011). RCP 8.5 is a high-emission baseline scenario reaching 8.5 W m^{-2} by 2100 with no explicit mitigation policy (Riahi et al., 2011). Projected global mean sea level rise values are summarised in Table 1. All six values are the upper bound of the model spread for total sea level change given in IPCC (2013, Table 13.8), which groups the extended scenarios by greenhouse gas concentration: the low category (below 500 ppm CO_2-eq, including RCP 2.6) gives 0.26 to 0.53 m at 2100, 0.41 to 0.85 m at 2300 and 0.50 to 1.02 m at 2500, and the high category (above 700 ppm, including RCP 8.5) gives 0.21 to 0.83, 0.92 to 3.59 and 1.51 to 6.63 m at the same horizons. Taking the upper bound throughout is a deliberate choice, consistent with the communication goal of illustrating plausible worst-case impacts, and it means the figures in Table 1 should be read as the high end of an assessed spread rather than as central estimates. We note that the 2100 value for the high category (0.83 m) sits marginally above the likely-range upper bound for RCP 8.5 in the twenty-first-century projections of Table 13.5 (0.82 m), because Table 13.8 is built from a different and smaller set of extended simulations. AR5 attaches low confidence to the ice-sheet component of these extended projections, and that caveat carries through to every result reported here for 2300 and 2500. The 2300 and 2500 values come from the same source as those for 2100, namely the extended scenario runs assessed in IPCC (2013, Table 13.8 and Fig. 13.13). AR5 carries that table through to 2500, so the 2500 figures of 1.02 and 6.63 m are assessed values rather than an extrapolation, but they rest on a small number of simulations and on ice-sheet models to which AR5 attaches low confidence, and they should be read as the high end of that spread rather than as formal projections. We note that the AR5 RCP framework has since been superseded by the AR6 Shared Socioeconomic Pathway (SSP) framework (IPCC, 2021); implications of this are discussed in Sect. 5.1.

The simulations were also run using the IPCC Sixth Assessment Report (AR6; IPCC, 2021) projections for the Los Angeles tide gauge (PSMSL station 245), obtained from the NASA Sea Level Projection Tool (NASA, 2021), which distributes the projections assessed in Fox-Kemper et al. (2021). These are local projections of total sea level change, including the vertical land motion term, relative to a 1995–2014 baseline; because Los Angeles is subsiding they lie approximately 20 % below the AR6 global mean values at 2100 (0.33 m rather than 0.44 m for SSP1-2.6, and 0.63 m rather than 0.77 m for SSP5-8.5). AR6 provides station-level projections only as far as 2150, so the AR6 simulations cover 2100 and 2150 and the AR5 values are retained for the 2300 and 2500 horizons. Table 1 gives the AR5 values used as simulation inputs; the corresponding AR6 values for the Los Angeles tide gauge are given in the captions of Figs. 4 to 6, which show the AR5 and AR6 results side by side.

3.4 Flood simulation

Inundation was modelled using the ArcToolbox Raster Calculator. A cell was classified as flooded if its pixel value

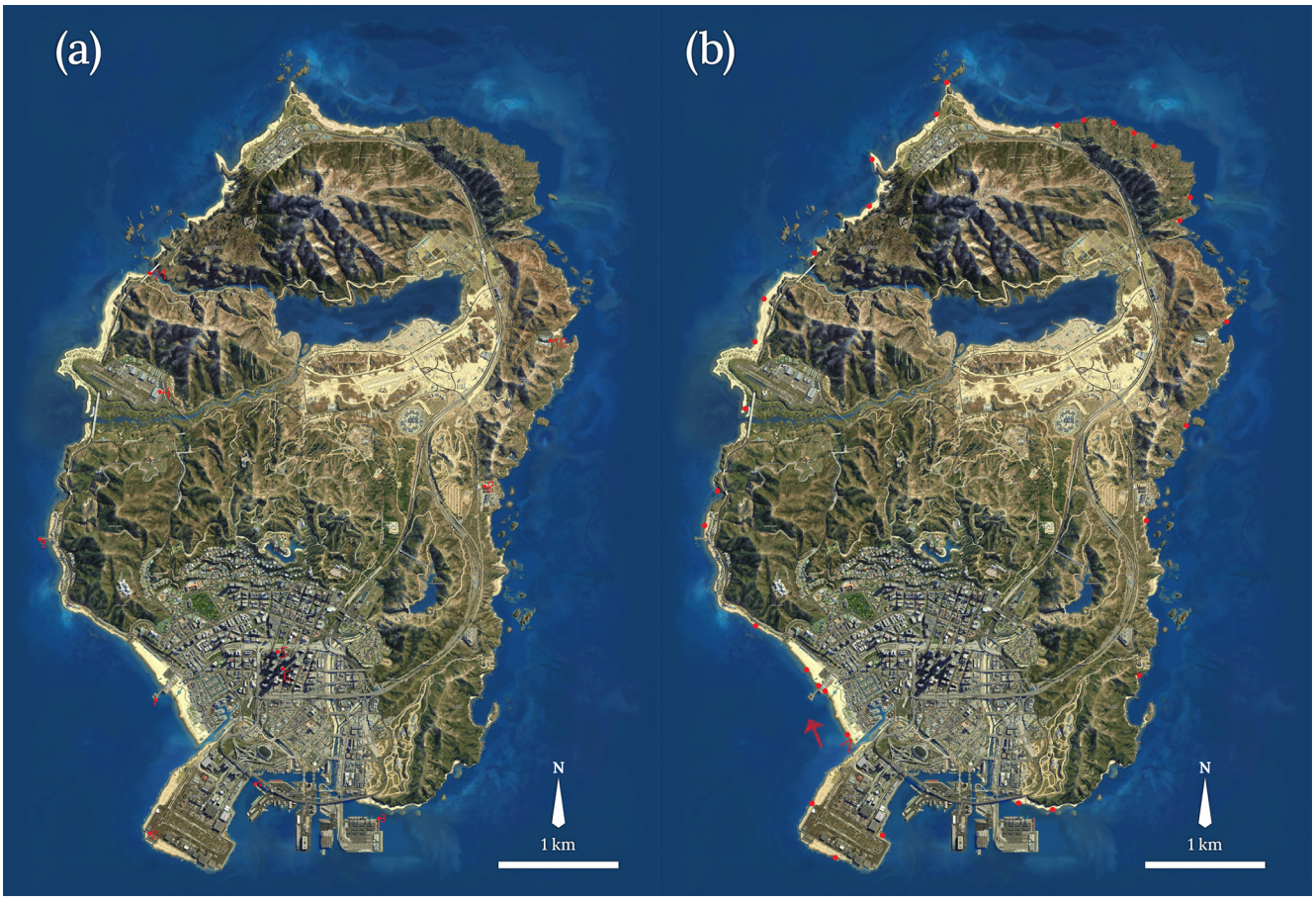


Figure 2. Terrain processing steps applied to the community-derived GTA V raster dataset. **(a)** The 11 ground control points (red dots) used for georeferencing, plotted on the satellite image of the game environment (Zier, 2013). **(b)** The 31 shoreline points (red dots) selected along sandy beaches to determine the mean sea level pixel datum (mean: −333.25, SD: 0.36). Base map: community reproduction of in-game terrain from Grand Theft Auto V, © Rockstar Games; reproduced for scholarly comment and not covered by the CC BY licence of this article.

Table 1. Sea level rise (SLR) values used in the inundation simulations, derived from IPCC AR5 (IPCC, 2013). The storm surge value (1.591 m) is the historical maximum tide recorded at the Los Angeles tide gauge on 10 January 2005 (NOAA, 2020). This is the highest still-water level in the gauge record and is applied as an upper-bound present-day extreme rather than a surge of any particular return period. Combined values (SLR + surge) are given for simulations including storm surge.

Scenario	SLR 2100 (m)	SLR 2300 (m)	SLR 2500 (m)	With surge: 2100/2300/2500 (m)
RCP 2.6	0.53	0.85	1.02	2.12/2.44/2.61
RCP 8.5	0.83	3.59	6.63	2.42/5.18/8.22

was less than or equal to the MSL datum pixel value plus the sea level rise increment plus, where applicable, the storm surge increment. This "bath-tub" approach assumes static inundation and hydraulic connectivity with the ocean, which is appropriate for first-order assessment of coastal flood extents. Static approaches of this kind are known to overestimate flood extent relative to hydrodynamic models, particularly where flow is constrained by topography or where an event is too short for the inundated volume to fill (Ramirez et al., 2016; Sanders et al., 2024). The maps presented below should therefore be read as showing land lying below a given still-water level, not as predictions of where water would actually reach during a specific event. The connectivity assumption merits attention in the game context: the community-derived raster dataset has a native cell size of approximately 2 m and does not resolve individual building footprints or road embankments as barriers. In reality such features would impede hydraulic connectivity and re-

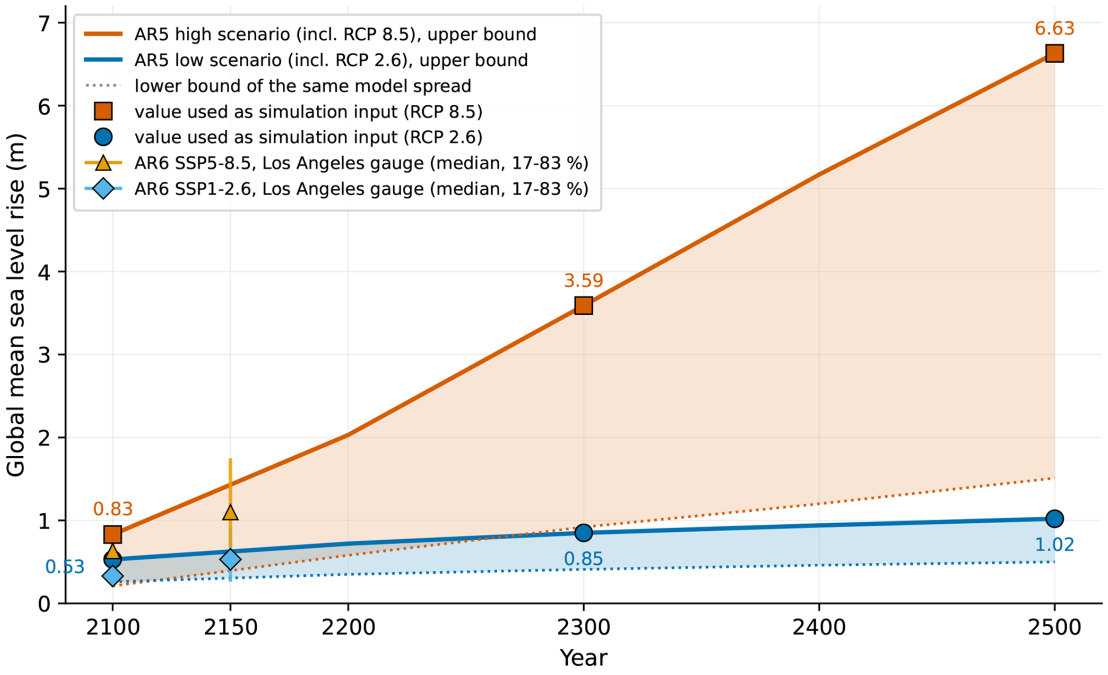


Figure 3. Projected global mean sea level rise from 2100 to 2500 for the AR5 extended scenario categories (IPCC, 2013, Table 13.8). Solid lines and shaded bands give the upper and lower bounds of the model spread for the low category, which includes RCP 2.6 (blue), and the high category, which includes RCP 8.5 (vermillion). Circles and squares mark the six upper-bound values used as simulation inputs, labelled in metres. Diamonds and triangles give the IPCC AR6 projections for the Los Angeles tide gauge (PSMSL station 245) at 2100 and 2150 as medians with 17th to 83rd percentile ranges; AR6 provides no station-level projection beyond 2150. AR5 attaches low confidence to the ice-sheet contribution in these extended projections.

duce inland flood propagation, meaning the model may overestimate the lateral extent of flooding in densely built areas such as the Vespucci district. Four simulation types were run for each of three time horizons (2100, 2300, and 2500): (i) RCP 2.6 without storm surge; (ii) RCP 2.6 with storm surge; (iii) RCP 8.5 without storm surge; and (iv) RCP 8.5 with storm surge. Storm surge was parameterised as the historical maximum tide recorded at the Los Angeles gauge (1.591 m a.m.s.l.; NOAA, 2020), applied as a fixed additive term representing an upper-bound extreme event. Flooded pixels were isolated using the Reclassify tool and results are reported as absolute area (km^2) and as a percentage of total land area.

4 Results

4.1 Flood extents under RCP 2.6

Without storm surge, RCP 2.6 produces modest inundation that grows slowly across the simulation period (Table 2). A sea level rise of 0.53 m by 2100 floods 0.24 km^2 (0.54 % of land area), primarily the marina channels in Vespucci and adjacent low-lying streets within one block of the waterfront. By 2300, a rise of 0.85 m extends inundation to 0.39 km^2 (0.87 %), and by 2500 a rise of 1.02 m reaches 0.46 km^2 (1.03 %). In all three horizons, inundation remains confined to incremental beach retreat around the island with no major infrastructure threatened.

Including the historical storm surge, extreme sea levels reach 2.12 m (2100), 2.44 m (2300), and 2.61 m (2500). Flooded areas increase substantially to 0.87 km^2 (1.97 %), 0.98 km^2 (2.21 %), and 1.03 km^2 (2.33 %) respectively. The relatively small differences across the three surge-inclusive estimates reflect the fact that the storm surge (1.59 m) dominates the combined water level: additional SLR between horizons inundates terrain already nearly at the surge waterline, leaving little additional low-lying land to flood. Under all RCP 2.6 scenarios, the airport, harbour, wastewater treatment plant, and gasworks remain above water. Under these conditions, the Vespucci marina area is inundated within approximately two blocks, all adjacent streets are flooded, Vespucci Beach is almost completely submerged, and residential properties in Chumash south of the pier are affected.

4.2 Flood extents under RCP 8.5

RCP 8.5 produces markedly larger inundation, especially at multi-century horizons (Table 2). Without storm surge, a rise of 0.83 m by 2100 floods 0.37 km^2 (0.85 %), similar in extent to RCP 2.6 conditions in 2300, an illustration of the near-term convergence of the two pathways. By 2300, with a rise of 3.59 m, inundation reaches 1.52 km^2 (3.42 %): the

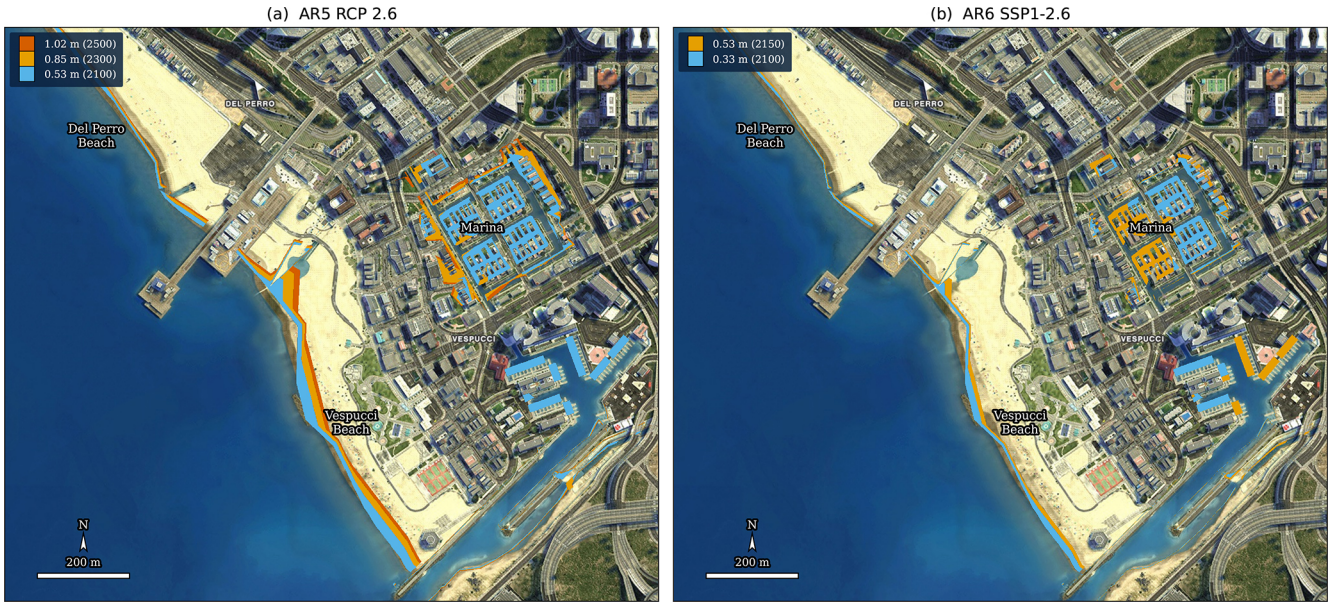


Figure 4. Flood inundation extents in Los Santos under a low-emission pathway without storm surge, at the Vespucci marina and Del Perro Beach; for the same pathway with storm surge see Fig. S2. Panel **(a)**, IPCC AR5 RCP 2.6: sea level rise of 0.53 m at 2100 (light blue), 0.85 m at 2300 (orange) and 1.02 m at 2500 (vermillion). Panel **(b)**, IPCC AR6 SSP1-2.6 for the Los Angeles tide gauge: 0.33 m at 2100 (light blue) and 0.53 m at 2150 (orange). Each colour shows the cumulative flooded area at that sea level, including the area of the underlying layer. Colour classes in Figs. 4 to 6 and in the Supplement follow the colour-blind-safe palette of Okabe and Ito (2008). Base map: community reproduction of in-game terrain from Grand Theft Auto V, © Rockstar Games; reproduced for scholarly comment and not covered by the CC BY licence of this article.

marina in Vespucci is nearly completely flooded, Del Perro Beach loses approximately half its area, and the eastern section of the Port of South Los Santos is submerged. By 2500, a rise of 6.63 m inundates 2.55 km^2 (5.75 %): Vespucci is completely flooded, the new shoreline extends into Little Seoul, and Chumash is nearly entirely lost. The harbour of South Los Santos and the gasworks are inoperable, and parts north of the airport are flooded though the runway itself remains above water. These results confirm the near-term convergence of the two scenarios and the substantially greater long-term sensitivity of the high-emission pathway.

Including storm surge under RCP 8.5 produces the most extreme scenarios in this analysis. Extreme sea levels of 5.18 m in 2300 flood 2.25 km^2 (5.08 %), with all of Chumash, the Paleto Bay pier, and virtually all beaches except those near Fort Zancudo submerged. At this horizon the port, wastewater infrastructure, and gasworks are rendered non-functional. By 2500, with an extreme sea level of 8.22 m, 2.89 km^2 (6.51 %) of land is inundated. The beach near Fort Zancudo remains the only substantial coastal strip above water, and all major port, wastewater, and energy infrastructure is permanently non-functional.

5 Discussion

The discussion below is organised around the two questions set out in Sect. 1. Section 5.1 considers the methodological limitations bearing on the first question, how reliably the Los Santos terrain can support GIS-based flood modelling. Section 5.2 addresses the second question through a structured comparison with published Los Angeles vulnerability analyses. Section 5.3 then considers which communication and outreach applications the approach can responsibly support.

5.1 Methodological limitations

The simulations rest on three main sources of uncertainty that must be acknowledged. First, the terrain dataset is community-derived and its absolute vertical accuracy cannot be formally validated against surveyed benchmarks. The shoreline determination procedure, which averaged pixel values across 31 manually selected beach points verified by in-game helicopter overflight, yielded an inter-point standard deviation of only 0.36 pixel units, suggesting internal consistency, but the absolute correspondence between the MSL datum and the true in-game sea surface is inherently approximate. This uncertainty is most consequential for the near-term, low-sea-level-rise scenarios where the margin between flooded and unflooded pixels is smallest. The close qualitative agreement with independent flood maps for Los Angeles (discussed below) nevertheless supports the overall reliability of the approach for first-order communication purposes.

Second, the storm surge parameterisation, a fixed additive term equal to the historical maximum tide gauge record

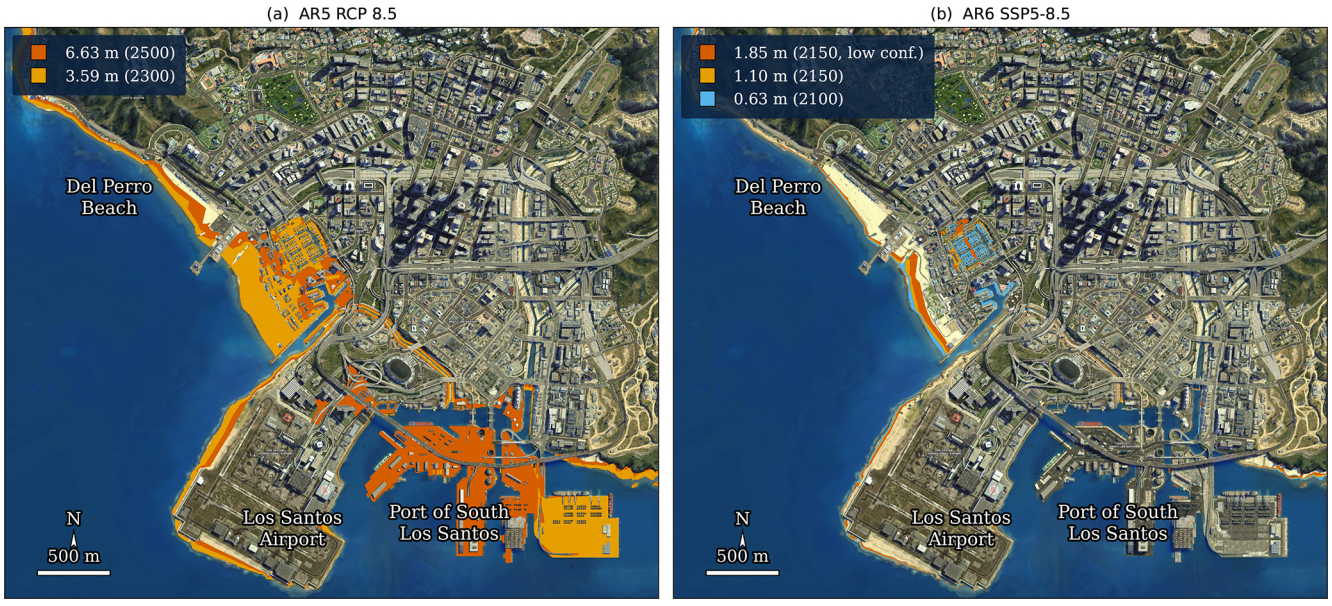


Figure 5. Flood inundation extents in Los Santos without storm surge, covering the city centre, the airport and the port district. Panel **(a)**, IPCC AR5 RCP 8.5: sea level rise of 3.59 m at 2300 (orange) and 6.63 m at 2500 (vermillion). Panel **(b)**, IPCC AR6 SSP5-8.5 for the Los Angeles tide gauge: 0.63 m at 2100 (light blue), 1.10 m at 2150 (orange) and 1.85 m at 2150 under the low-confidence branch (vermillion). Each colour shows the cumulative flooded area at that level, including the area of the underlying layer. The AR5 extent for 2300 is broadly comparable to the combined RCP 2.6 and storm surge scenario shown in Fig. S2, illustrating the near-term convergence of the two pathways. Key locations are labelled. Base map: community reproduction of in-game terrain from Grand Theft Auto V, © Rockstar Games; reproduced for scholarly comment and not covered by the CC BY licence of this article.

Table 2. Summary of inundation results for Los Santos under all scenario and storm-surge combinations. Areas given in km^2 and as percentage of total land area (44.4 km^2). Storm surge of 1.591 m (Los Angeles historical maximum, NOAA, 2020) is added where indicated.

Horizon	RCP 2.6 no surge km^2	%	RCP 2.6 + surge km^2	%	RCP 8.5 no surge km^2	%	RCP 8.5 + surge km^2	%
2100	0.24	0.54	0.87	1.97	0.37	0.85	0.97	2.19
2300	0.39	0.87	0.98	2.21	1.52	3.42	2.25	5.08
2500	0.46	1.03	1.03	2.33	2.55	5.75	2.89	6.51

(1.591 m; NOAA, 2020), is a simplification. It does not account for changes in storm climatology under warming, nor for non-linear interactions between elevated mean sea level and storm surge propagation. Results including storm surge are therefore best interpreted as conservative extreme-event estimates, not expected conditions. A probabilistic approach drawing on return-period analysis of the LA tide gauge record would be more rigorous and is recommended for future work.

Third, the scenario framework differs between the two halves of the comparison. The Los Santos simulations are run under both AR5 RCP and AR6 SSP projections (Sect. 3.3), but the peer-reviewed inundation studies for Los Angeles against which we validate (Grifman et al., 2013; Moffatt & Nichol, 2018) both pre-date AR6 and use scenario values broadly comparable to AR5. More recent flooding work for the region (Sanders et al., 2023; Schubert et al., 2024) addresses rainfall-driven and storm-tide flooding rather than long-horizon sea level inundation, and does not provide district-level maps equivalent to those of Grifman et al. (2013). The structured comparison in Sect. 5.2 therefore rests on the AR5 runs, which are the ones with a like-for-like counterpart; the AR6 runs extend the scenario range but cannot at present be validated against an AR6-based Los Angeles study. This matters less than it might, because the spatial pattern of inundation is primarily a function of terrain rather than of the precise water level: moving from AR5 to AR6 changes the modelled 2100 extent by 24 % to 40 % without storm surge but by only 7 % to 8 % once the surge is included, and leaves the sequence in which districts flood unchanged. AR6-based vulnerability mapping for Los Angeles, against which the AR6 runs could be validated directly, remains a clear priority for future work.

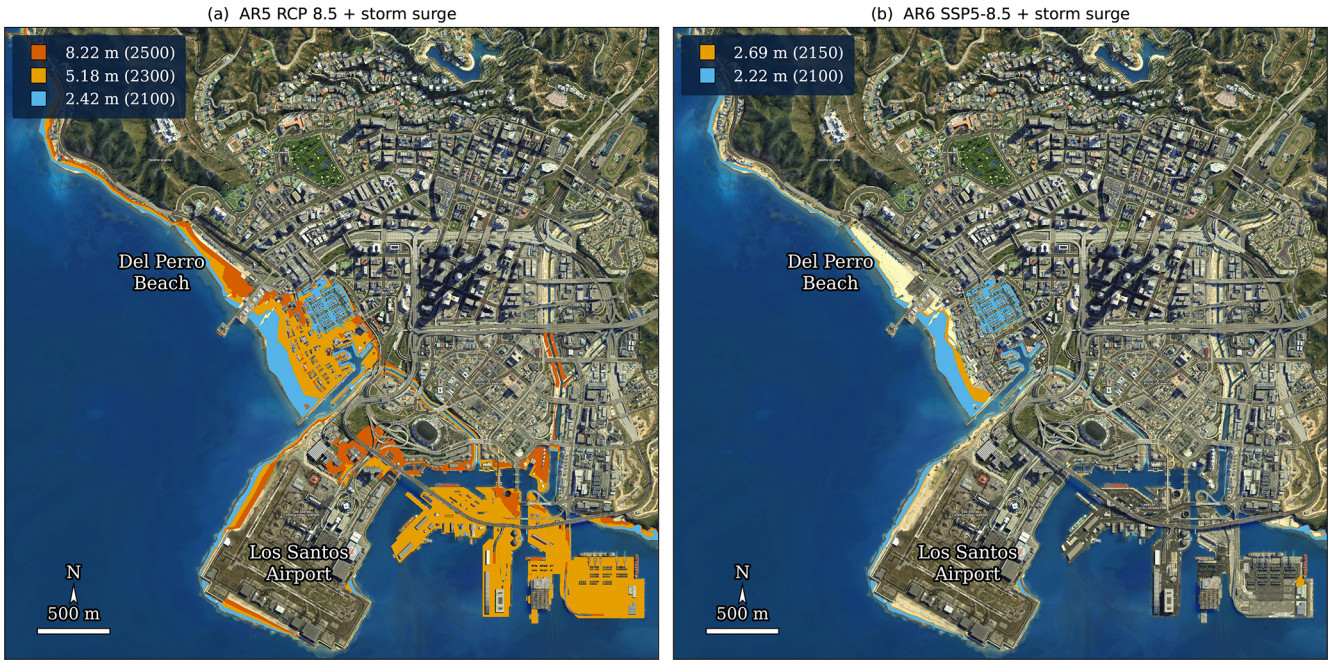


Figure 6. Flood inundation extents in Los Santos with the historical storm surge added (1.591 m, the maximum still-water level in the Los Angeles tide gauge record; NOAA, 2020). Panel **(a)**, IPCC AR5 RCP 8.5: extreme sea levels of 2.42 m at 2100 (light blue), 5.18 m at 2300 (orange) and 8.22 m at 2500 (vermillion). Panel **(b)**, IPCC AR6 SSP5-8.5 for the Los Angeles tide gauge: 2.22 m at 2100 (light blue) and 2.69 m at 2150 (orange); AR6 provides no station-level projection beyond 2150, so the AR5 panel carries the later horizons. Each colour shows the cumulative flooded area at that level, including the area of the underlying layer. Key infrastructure (airport, port, wastewater plant) is labelled. Base map: community reproduction of in-game terrain from Grand Theft Auto V, © Rockstar Games; reproduced for scholarly comment and not covered by the CC BY licence of this article.

The bath-tub inundation model also ignores dynamic coastal processes including wave action, land subsidence, morphological change, and erosion. Land subsidence is particularly relevant for Los Angeles: parts of the harbour district and former wetland areas around the port are subject to measurable local subsidence (up to several millimetres per year; Blackwell et al., 2020), meaning that the real-world flood threshold in these areas may be lower than our model implies, and the convergence with Grifman et al. (2013) for the port district may therefore slightly underestimate future risk. The Bruun Rule predicts significant beach retreat under the sea level rises modelled here (Bruun, 1988), and Grifman et al. (2013) flag erosion-driven road damage on the Pacific Coast Highway corridor as a key impact not captured by static inundation mapping. The game itself introduces additional geomorphological artefacts: abrupt transitions between landscape types that are unrealistic, the absence of the Ballona Creek wetlands south of Marina del Rey, and a ria-like appearance of the Zancudo River delta that has no counterpart in California. These limitations are inherent to the entertainment context of the source data and must be communicated explicitly when the exercise is used in an educational setting.

5.2 Comparison with Los Angeles vulnerability analyses

Despite these limitations, the Los Santos flood patterns correspond closely to flood projections for Los Angeles based on the USGS Coastal Storm Modeling System (CoSMoS v3.0 Phase 2; Barnard et al., 2018), as well as to published vulnerability analyses (Grifman et al., 2013; Moffatt & Nichol, 2018). The comparison is illustrated in Fig. 7, where the left-column panels show CoSMoS-derived flood extents (100-year storm + 1.0 m SLR, corresponding to approximately 3 m combined extreme sea level) overlaid on satellite imagery, and the right-column panels show the corresponding Los Santos results from this study. While Fig. 7 uses CoSMoS v3.0 outputs as the primary visual comparison, the narrative discussion below also draws on the published vulnerability analyses of Grifman et al. (2013) and Moffatt & Nichol (2018), which interpret CoSMoS outputs in a policy planning context. We discuss the three comparison areas in detail.

The Vespucci/Venice Beach comparison is the most instructive. Both our simulations and Grifman et al. (2013) identify the marina and canal district as the primary flood zone at storm surge levels approaching 3 m, with the beach frontage also substantially inundated. The key discrepancy is the absence in GTA V of the Ballona Creek wetland immediately south of Marina del Rey, which in reality would be

Table 3. Qualitative comparison of flood impact patterns between Los Santos (this study) and Los Angeles (Grifman et al., 2013; Moffatt & Nichol, 2018) at comparable extreme sea levels (∼ 3 m).

District pair	Los Santos (this study)	Los Angeles (CoSMoS v3.0; Barnard et al., 2018; Grifman et al., 2013; Moffatt & Nichol, 2018)
Vespucci/Venice Beach	Marina channels and surrounding streets flooded (∼ 2 blocks); Vespucci Beach largely inundated; airport unaffected	Marina del Rey and canal district flooded; airport unaffected; Ballona Creek wetlands inundated (absent in game)
Chumash/Malibu–Pacific Palisades	Beach inundated; Great Ocean Highway not directly flooded but erosion expected; no road inundation in static model	Pacific Coast Highway threatened by erosion under SLR (Bruun Rule); direct inundation limited at ∼ 3 m surge
Port of South Los Santos/Port of Los Angeles	No flooding at 2.61 m (RCP 2.6 + surge, 2500); complete flooding at 5.18 m (RCP 8.5 + surge, 2300)	No flooding mapped at ∼ 3 m storm + SLR; future risk at higher sea levels acknowledged

inundated early and extend the flooded zone further inland than our model predicts. Instead, the GTA V map places the Los Santos International Airport directly south of the canal, which we interpret as a deliberate editorial compression of the landscape for game design purposes, although this is our reading of the map rather than something confirmed by the developers. Crucially, both analyses agree that the airport is not threatened under comparable scenario assumptions, providing a specific and verifiable point of convergence.

For the Pacific Palisades/Chumash corridor, both analyses find limited direct inundation of the coastal highway under ∼ 3 m extreme sea levels, with the primary risk being erosion-driven road damage. The Bruun Rule predicts significant beach retreat under the sea level rises modelled here, but this dynamic process is not captured by either the present bath-tub model or the direct-inundation approach of Grifman et al. (2013). The convergence of conclusions despite methodological independence is therefore particularly meaningful: both approaches arrive at a diagnosis of erosion risk rather than direct inundation for this corridor.

A third point of convergence concerns the port district, illustrated in panels (e) and (f) of Fig. 7. In our simulations the Port of South Los Santos remains above water at combined extreme sea levels up to 2.61 m (RCP 2.6 + surge, 2500), but is completely inundated at 5.18 m (RCP 8.5 + surge, 2300). Grifman et al. (2013) map no flooding in the Port of Los Angeles under their comparable 2010 storm scenario but explicitly flag the port as at risk under higher future sea levels. This third comparison further supports the conclusion that the GTA V terrain reproduces the broad spatial structure of coastal flood risk with sufficient fidelity to be scientifically meaningful for communication purposes.

5.3 Applications in communication and outreach

The correspondence documented in Sect. 5.2 is what gives the Los Santos terrain any communication value at all: a game landscape that behaved unlike the city it depicts would be an engaging prop but not an informative one. A formal classroom setting is nonetheless the wrong place to use it. GTA V carries an 18+ rating in Germany and in most other jurisdictions. Removing the objectionable content is technically straightforward: the game has a large and active modding community, and mods that strip out weapons, violence, and other adult material are commonplace, so an age-appropriate build is certainly achievable and was the route the underlying thesis proposed. The obstacle is not feasibility. It is that the familiarity such a lesson would trade on comes from the unmodified game, which the intended age group is not supposed to have played, so the pedagogical premise and the legal position pull against each other; and that building, distributing and maintaining a classroom-safe build across a school's machines would demand an effort comparable to producing a purpose-made environment. Where a classroom exercise is the goal, an openly licensed world such as the Minecraft-based CoastCraft materials (Environment Agency, 2025) is the more appropriate vehicle, with the further advantage that it can depict a real city rather than a fictional analogue.

The applications we would argue for are non-formal. The flood layers produced here are of direct interest to the community of games and climate creators who already work with GTA V, where a quantitative, source-documented projection can displace the speculative flooding scenarios that circulate informally, and where individual creators reach audiences far larger than any classroom sequence could. Museum and science-centre installations built on familiar virtual environments are a second route. A third, and in our view the most valuable, concerns media literacy about flood maps themselves: static inundation images of this kind circulate widely in public climate communication and are a recognised source of misinformation when a map of land lying below a water level is read as a map of where water will actually go (Ramirez et al., 2016; Sanders et al., 2024). A recognisable



Figure 7. Side-by-side comparison of flood inundation patterns between Los Angeles (left column, panels **a**, **c**, **e**) and Los Santos (right column, panels **b**, **d**, **f**). The Los Angeles panels show flood extents from CoSMoS v3.0 Phase 2 (Barnard et al., 2018) for the 100-year storm combined with 1.0 m of sea level rise, approximately 3 m of combined extreme sea level, on an ESRI World Imagery basemap. The Los Santos panels show the modelled water surface at 2.61 m, the RCP 2.6 combined extreme sea level for 2500. **(a)** Venice Beach and Marina del Rey, Los Angeles; **(b)** the Vespucci marina and Del Perro, Los Santos. **(c)** Pacific Palisades and the Pacific Coast Highway, Los Angeles; **(d)** Pacific Bluffs and the Great Ocean Highway, Los Santos. **(e)** Port of Los Angeles; **(f)** Port of South Los Santos. The two scenarios are broadly comparable but not identical. Pink shading denotes the modelled water surface at the stated level in all panels; in the Los Santos panels it includes water bodies already present at mean sea level, so it is not a map of newly inundated land, for which areas are given in Table 2. Each panel carries its own scale bar and the panels are at differing scales. CoSMoS data: https://doi.org/10.5066/F7T151Q4 (Barnard et al., 2018). Satellite imagery in panels **(a)**, **(c)** and **(e)**: Imagery © 2026 Esri, Maxar, Earthstar Geographics, and the GIS User Community | Powered by Esri. Imagery in panels **(b)**, **(d)** and **(f)**: Base map: community reproduction of in-game terrain from Grand Theft Auto V, © Rockstar Games; reproduced for scholarly comment and not covered by the CC BY licence of this article.

game world is an unusually good place to make that distinction visible, because the audience can navigate the terrain themselves and see what the model does and does not represent. Whichever route is taken, the limitation stated in Sect. 3.4 has to travel with the figures.

6 Conclusions

We present what we believe to be the first quantitative GIS-based climate impact simulation conducted on terrain data derived from a commercial video game, and the first to validate the results against peer-reviewed vulnerability analyses for the real city that inspired the game environment. Under IPCC AR5 RCP 8.5 with historical storm surge, combined sea levels projected at 5.18 m for 2300 give 5.1 % of the mapped land area of Los Santos as inundated in the model, placing the port, wastewater infrastructure, and coastal energy facilities at risk. At the 2500 horizon (IPCC, 2013, Table 13.8), for which AR5 attaches low confidence to the ice-sheet contribution, sea levels of 8.22 m extend modelled inundation to 6.5 % of land area, with the beach near Fort Zancudo the only substantial coastal strip remaining above the modelled water level. Under the mitigation scenario RCP 2.6, modelled inundation at 2300 is limited to 2.2 % of land area with storm surge and no major infrastructure affected, illustrating the spatial consequences of divergent climate policy trajectories in a geographically recognisable urban environment.

Qualitative comparison with published vulnerability analyses for Los Angeles confirms close spatial correspondence in flood patterns across three representative district pairs: the marina and canal district (Vespucci/Venice Beach), the Pacific Palisades coastline (Chumash/Malibu), and the harbour (Port of South Los Santos/Port of Los Angeles). This congruence supports the conclusion that the GTA V terrain is sufficiently faithful to real-world morphology to be scientifically meaningful for first-order coastal flood communication. The epigraph that opens this paper, voiced by Franklin Clinton, one of the three main protagonists of GTA V, captures something important about the stakes: the question is not only what will flood, but whether the medium through which we communicate that risk is one that matters to the people who need to hear it. We argue that for the generation that grew up in Los Santos, it does.

We recommend the approach as a template for geoscience communication using open-world video game environments, with the explicit caveat that the static inundation model and its limitations must be communicated transparently to every audience, and that the 2300 and 2500 horizons remain the weakest part of the scenario set. The potential for game engines to serve as platforms for dynamic, real-time climate impact visualisation represents a frontier that geoscience communicators and game developers should explore together.

Code and data availability. The GTA V community terrain model is publicly available at https://sketchfab.com/3d-models/map-gta5-f622784b2fa9453fb20821afb74a9cb6 (Somnit, 2020). The model was withdrawn by its author after our analysis was completed and the file is no longer obtainable; the archived page (https://web.archive.org/web/20201111153042/https://sketchfab.com/3d-models/map-gta5-f622784b2fa9453fb20821afb74a9cb6, last access: 3 November 2026) documents the source that was used. The CoSMoS v3.0 Phase 2 flood hazard shapefiles for Los Angeles County (used for the Los Angeles panels in Fig. 7) are available from the USGS ScienceBase Catalog at https://doi.org/10.5066/F7T151Q4 (Barnard et al., 2018). Flood data can also be visualised interactively via the Our Coast Our Future web platform at https://ourcoastourfuture.org (last access: 3 November 2026). The ArcGIS processing workflow is described in full in Sect. 3. NOAA tide gauge data for Los Angeles are available at https://tidesandcurrents.noaa.gov (last access: 11 June 2020, NOAA, 2020). The terrain mesh itself is a community reproduction of a proprietary Rockstar Games asset and is therefore not ours to redistribute; readers should obtain it from the Sketchfab link above (Somnit, 2020). The modelled flood extents for every scenario in Tables 1 and 2, as raster and vector layers, the scenario table and the code that produced them are available at https://doi.org/10.5281/zenodo.23932368 (Nörenberg and Lantuit, 2026). The calibrated digital elevation model is a derivative of a community reproduction of a proprietary Rockstar Games asset and is not redistributed; the calibration constants in Sect. 3 are sufficient to reproduce it from the source mesh.

Supplement. The Supplement contains full-island flood extent maps. Figures S1 to S4 give the four AR5 scenario and storm-surge combinations at the three time horizons presented here, and Figs. S5 and S6 give the corresponding AR6 extents for SSP1-2.6 and SSP5-8.5 at 2100 and 2150. The georeferencing control points and shoreline determination points are shown in Fig. 2 of the main text. The supplement related to this article is available online at https://doi.org/10.5194/gc-9-537-2026-supplement.

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Ethical statement. This study does not involve human participants, personal data, animal subjects, sensitive ecosystems, or hazardous materials. The research is based entirely on publicly available digital terrain data, published climate projections, and open-access coastal hazard model outputs. No ethical approval from an institutional review board or professional body was required or sought.

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