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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 extracted 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 RCP 8.5 conditions with storm surges, combined sea levels of up to 5.18 m by 2300 would inundate 5.1 % of the mapped land area; in a longer-term illustrative projection to 2500, extreme sea levels of 8.22 m would inundate 6.5 %, rendering the port, wastewater infrastructure, and coastal energy facilities permanently non-functional. The mitigation scenario RCP 2.6 limits inundation to 2.2 % of land area at 2300 with no major infrastructure at risk. We evaluate the potential of this approach for geoscience communication and education in some detail, grounding the case in psychological-distance theory and in a six-lesson classroom sequence developed as part of the underlying thesis and aligned with an official state curriculum: the intrinsic familiarity of the Los Santos environment offers an affective engagement with climate change impacts that conventional visualisation struggles to achieve, provided its geomorphological and representational limitations are taught alongside it.

"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.

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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 in this emerging "geo-gaming" literature 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 Iceland (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 and 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 three 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? Third, what is the potential of this approach, and of GTA V specifically, as a geoscience communication and education tool? We treat this third question as a central aim of the paper rather than as a closing remark: the terrain validation reported in Sects. 4 and 5.2 exists in part to give the communication argument something firmer to stand on than familiarity alone, and Sect. 5.3 develops it with its own conceptual grounding, a proposed classroom sequence, and an explicit account of its limits. 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 both the scientific and educational implications. To our knowledge, this is the first study to perform a quantitative GIS-based climate impact simulation using terrain data extracted from a commercial video game, and to validate the results against peer-reviewed analyses of the real-world location that inspired it.

2 Study area

Los Santos is the primary setting of GTA V and occupies a coastal island of approximately 44.4 km² of land area within the game world (total map area 74.3 km² 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

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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 and Nichol, 2018) provide the comparative baseline for this study.

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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). Source: community satellite image of the GTA V game environment.

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

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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 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 (blender.org) 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.

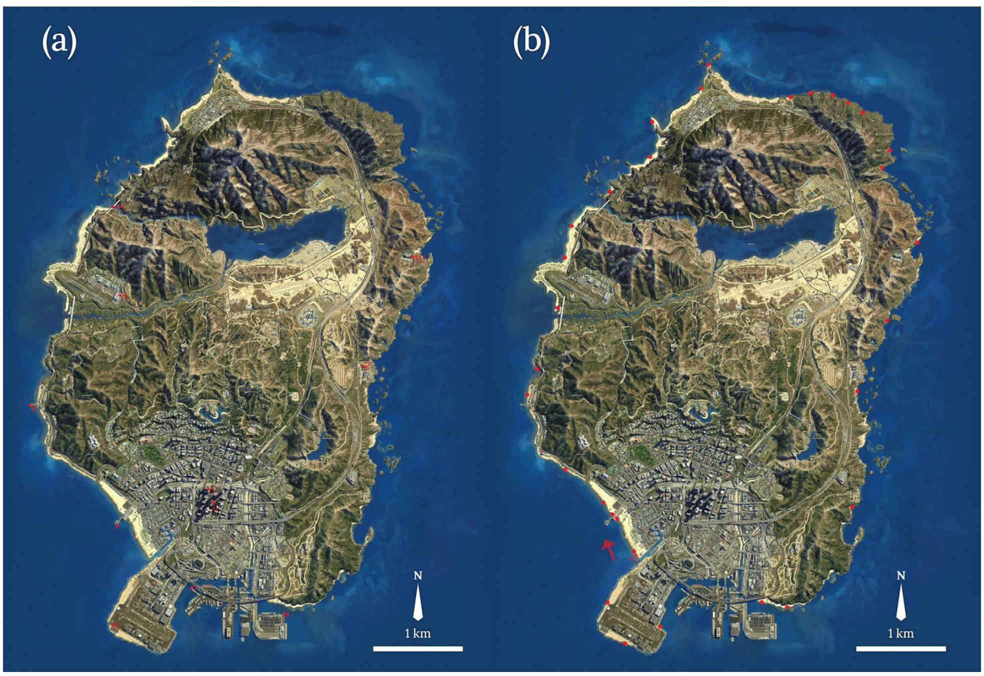

Figure 2. Terrain processing steps applied to the community-derived GTA V raster dataset. (a) The 11 ground control points (red dots) used for georeferencing, plotted on the satellite image of the game environment (Zier, 2013). (b) The 31 shoreline points (red dots) selected along sandy beaches to determine the mean sea level pixel datum (mean: −333.25, SD: 0.36). Source: community satellite image of the GTA V game environment.

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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 1 m × 1 m cell size.

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. For RCP 8.5, the value used at 2100 (0.83 m) is drawn from the AR5 Chapter 13 scenario tables and lies marginally above the stated likely range upper bound (0.82 m; IPCC, 2013, Table 13.5), lying at the upper boundary of the AR5 likely range for RCP 8.5. This value was selected to provide a conservative upper-bound estimate consistent with the communication goal of illustrating plausible worst-case near-term impacts. For RCP 2.6, the 2100 value (0.53 m) is the AR5 likely-range median. Multi-century projections to 2300 are taken from the AR5 extended scenario runs (IPCC, 2013, Fig. 13.14). To provide a longer-term illustrative perspective, we additionally report results for 2500 using values from the World Ocean Review (Maribus, 2017), which synthesises the AR5 multi-century scenario extensions beyond 2300: 1.02 m for the low-emission scenario and 6.63 m for the high-emission scenario. These 2500 values carry very low confidence and should be interpreted as illustrative upper-bound extremes rather than

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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.

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, 2020a). 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	0.83	1.02	2.12 / 2.44 / 2.61	
RCP 8.5	0.83	3.59	6.63	2.42 / 5.18 / 8.22	

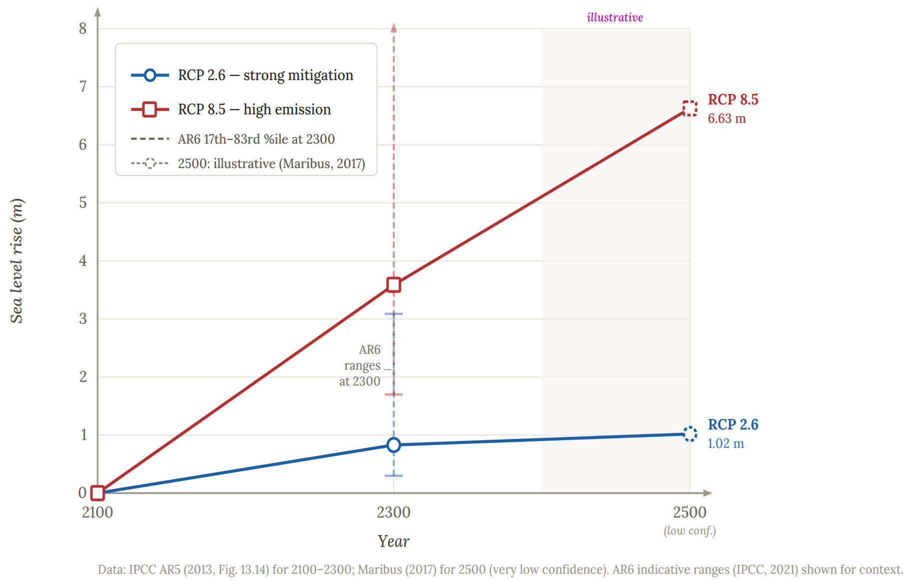

Figure 3. Maximum projected global mean sea level rise (m) from 2100 to 2500 under IPCC AR5 scenarios RCP 2.6 (blue) and RCP 8.5 (orange), derived from IPCC (2013, Fig. 13.14). Markers indicate the three time horizons used as simulation inputs: circles for RCP 2.6 and squares for RCP 8.5, at 2100 and 2300; the 2500 values (1.02 m and 6.63 m) are from Maribus (2017) and should be treated as illustrative extremes (very low confidence). Grey whiskers at 2300 show the indicative 17th–83rd percentile ranges from AR6 for SSP1-2.6 (0.3–3.1 m) and SSP5-8.5 (1.7–6.8 m) for context (IPCC, 2021).

3.4 Flood simulation

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

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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 reduce 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 above MSL; NOAA, 2020a), 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 (km²) 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 km² (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 0.83 m extends inundation to 0.39 km² (0.87 %), and by 2500 a rise of 1.02 m reaches 0.46 km² (1.03 %). In all three horizons, inundation remains confined to incremental beach retreat around the island with no major infrastructure threatened.

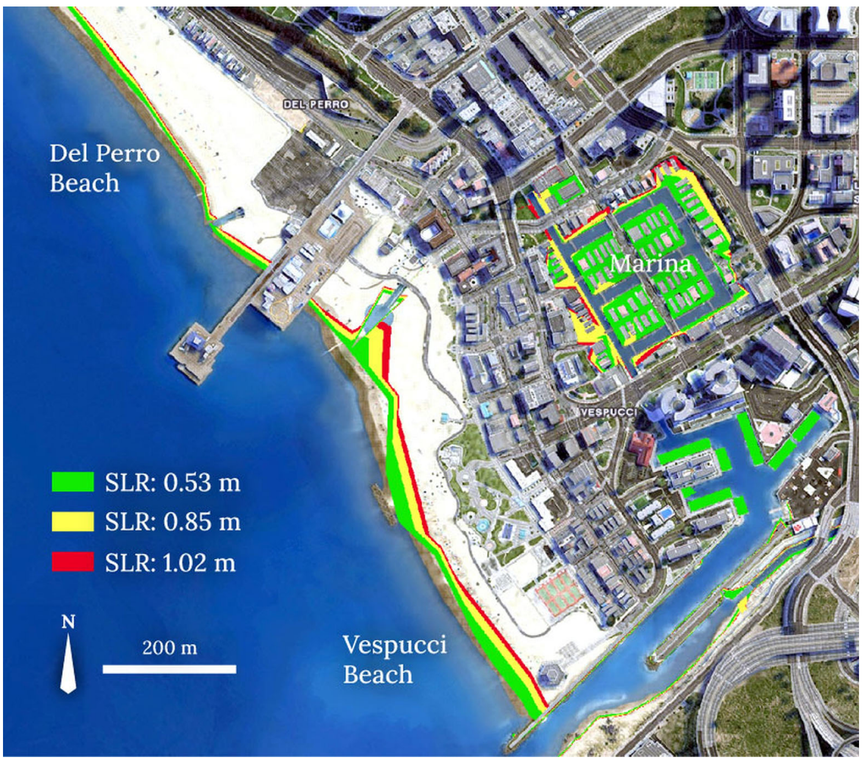

Figure 4. Flood inundation extents in Los Santos under RCP 2.6 without storm surge (for RCP 2.6 with storm surge, see Fig. 6 for the combined surge scenario). Green: sea level rise of 0.53 m (2100). Yellow: 0.83 m (2300). Each colour shows

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the cumulative flooded area at that sea level, including the area of the underlying layer. Inset shows detail of the Vespucci marina and Del Perro Beach area. Source: community satellite image of the GTA V game environment.

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 km² (1.97 %), 0.98 km² (2.21 %), and 1.03 km² (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 km² (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 km² (3.42 %): the 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 km² (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.

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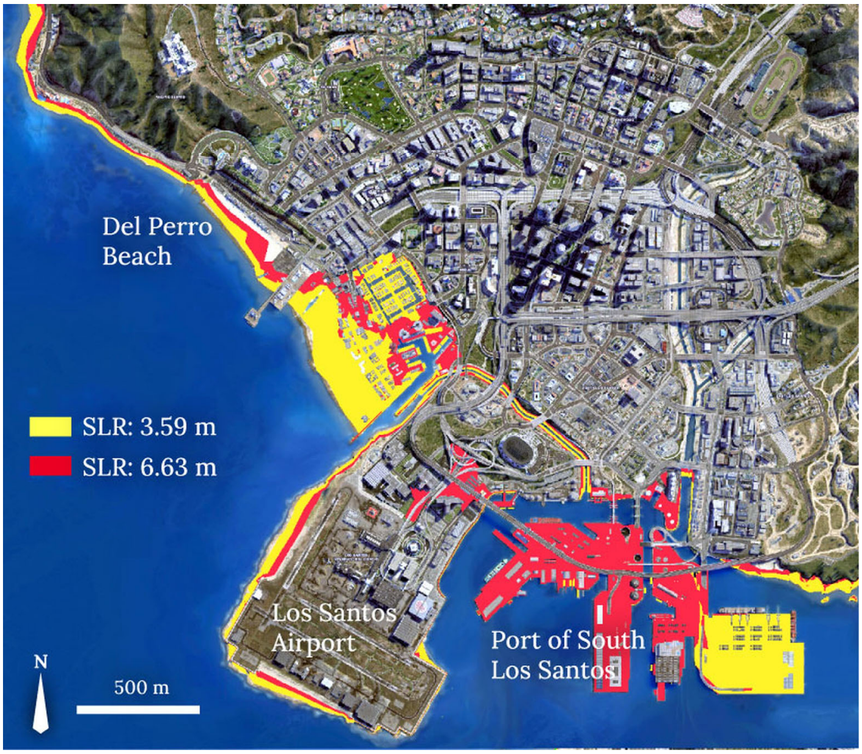

Figure 5. Flood inundation extents in Los Santos under RCP 8.5 without storm surge. Yellow: sea level rise of 3.59 m (2300). Red: 6.63 m (2500; illustrative, very low confidence; Maribus, 2017). The 2300 RCP 8.5 extent (yellow) is broadly comparable to the combined RCP 2.6 + storm surge scenario shown in Fig. 4, illustrating the near-term convergence of the two pathways. Key locations are labelled. Source: community satellite image of the GTA V game environment.

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 km² (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 km² (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.

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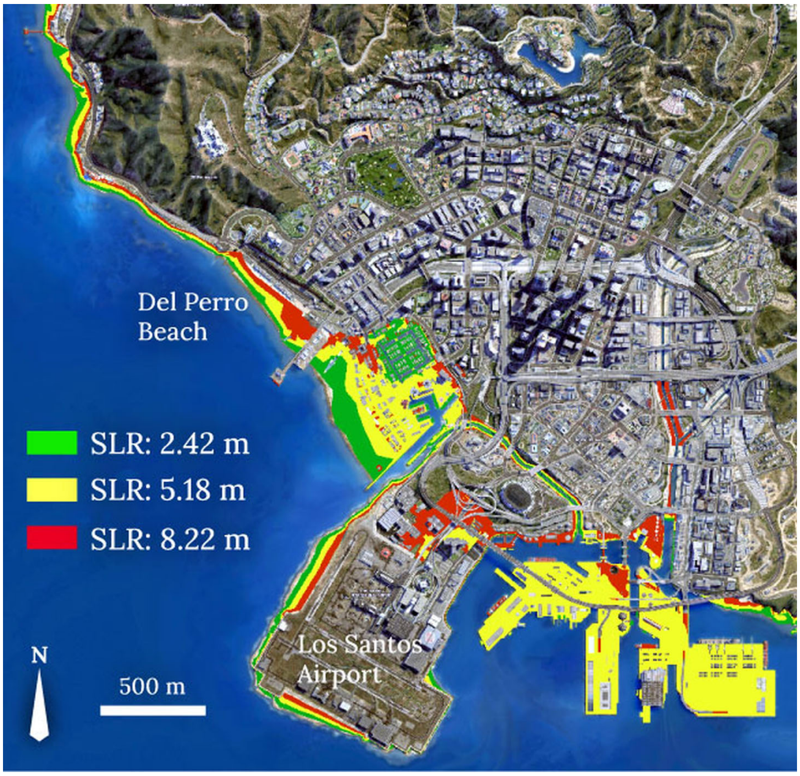

Figure 6. Flood inundation extents in Los Santos under RCP 8.5 with historical storm surge (1.591 m, Los Angeles maximum tide gauge record, NOAA, 2020a). Green: extreme sea level of 2.42 m in 2100. Yellow: 5.18 m in 2300. Red: 8.22 m in 2500. Key infrastructure (airport, port, wastewater plant) is labelled. Underlying layer includes the extent of the upper layer(s). Source: community satellite image of the GTA V game environment.

Table 2. Summary of inundation results for Los Santos under all scenario and storm-surge combinations. Areas given in km² and as percentage of total land area (44.4 km²). Storm surge of 1.591 m (Los Angeles historical maximum, NOAA, 2020a) is added where indicated.

Horizon	RCP 2.6 no surge km²	%	RCP 2.6 + surge km²	%	RCP 8.5 no surge km²	%	RCP 8.5 + surge km²	%
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

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5 Discussion

The discussion below is organised around the three questions set out in Sect. 1. Sect. 5.1 considers the methodological limitations bearing on the first question, how reliably the Los Santos terrain can support GIS-based flood modelling. Sect. 5.2 addresses the second question through a structured comparison with published Los Angeles vulnerability analyses. Sect. 5.3 then turns to the third question, the communication and educational potential of the approach, which we treat as being as central to this paper's contribution as the geomorphological validation that precedes it, and to which we devote correspondingly expanded space below.

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 (1.591 m; NOAA, 2020a), 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 simulations use IPCC AR5 (2013) RCP scenarios. The subsequent AR6 report (IPCC, 2021) revised the scenario framework to Shared Socioeconomic Pathways (SSPs) and updated projections upwards, particularly for the high-emission pathway: the AR6 likely range for SSP5-8.5 by 2100 is 0.63–1.01 m (relative to 1995–2014), compared with 0.45–0.82 m under AR5 RCP 8.5 (Fox-Kemper et al., 2021). At multi-century timescales, AR6 provides indicative ranges of 0.3–3.1 m for SSP1-2.6 and 1.7–6.8 m for SSP5-8.5 by 2300 (IPCC, 2021), which bracket the AR5 values used here: 0.83 m (RCP 2.6) falls within the SSP1-2.6 range of 0.3–3.1 m, while 3.59 m (RCP 8.5) falls within the SSP5-8.5 range of 1.7–6.8 m, albeit in the lower half of the latter range (the AR6 SSP5-8.5 central estimate at 2300 is approximately 2.5–3.0 m). Our 2300 results therefore remain within the range of current projections under the updated framework, though the RCP 8.5 value is not a central estimate but closer to the lower end of the AR6 high-emission range. Crucially, the scientific literature on sea level rise impacts specifically for Los Angeles (the real-world comparator for our validation) has not been updated to AR6 either. The two peer-reviewed inundation studies we compare against (Grifman et al., 2013; Moffatt and Nichol, 2018) both pre-date AR6 and use scenario frameworks broadly comparable to AR5 RCP values. More recent flooding work for the Los Angeles region (Sanders et al., 2023; Schubert et al., 2024) focuses on rainfall-driven and storm-tide flooding rather than long-horizon sea level rise inundation under SSP scenarios, and does not provide district-level flood maps equivalent to those of Grifman et al. (2013). This means that an AR6-based simulation of Los

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Santos would currently have no peer-reviewed Los Angeles counterpart against which to validate, which would undermine the comparative validation that is central to the paper's approach. Using consistent scenario generations across both the game-world simulation and the real-world validation is therefore not only pragmatic but methodologically coherent. The spatial patterns of inundation are in any case primarily a function of terrain topography rather than the precise scenario values, so the qualitative conclusions are robust to this issue. Re-running the simulations under AR6 projections, in tandem with updated AR6-based vulnerability mapping for Los Angeles, remains a clear and important priority for future work.

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 and 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 and Nichol (2018), which interpret CoSMoS outputs in a policy planning context. We discuss the three comparison areas in detail.

Table 3. Qualitative comparison of flood impact patterns between Los Santos (this study) and Los Angeles (Grifman et al., 2013; Moffatt and 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 and 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

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District pair	Los Santos (this study)	Los Angeles (CoSMoS v3.0; Barnard et al., 2018; Grifman et al., 2013; Moffatt and Nichol, 2018)
		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 3.59 m (RCP 8.5 + surge, 2300)	No flooding mapped at ~3 m storm + SLR; future risk at higher sea levels acknowledged

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 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, a deliberate editorial compression of the landscape for game design purposes. Crucially, both analyses agree that the airport is not threatened under comparable scenario assumptions, providing a specific and verifiable point of convergence.

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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) at comparable combined sea level extremes (~2.6 m for rows 1 and 2, and ~3.6 m for row 3; note that the Los Angeles panels use the CoSMoS 100-year storm + 1.0 m SLR scenario, corresponding to approximately 3 m combined extreme sea level, while the Los Santos panels show 2.61 m; the scenarios are broadly comparable but not identical). Los Angeles panels show flood extents derived from CoSMoS v3.0 Phase 2 (Barnard et al., 2018), 100-year storm + 1.0 m sea level rise scenario, on ESRI World Imagery satellite basemap. (a) Venice Beach and Marina del Rey, Los Angeles (CoSMoS v3.0); (b) Vespucci and Del Perro, Los Santos, RCP 2.6 + storm surge, 2.61 m (2500, illustrative). (c) Pacific Palisades and Pacific Coast Highway, Los Angeles (CoSMoS v3.0); (d) Chumash and Great Ocean Highway, Los Santos, RCP 2.6 + storm surge, 2.61 m (2500, illustrative). (e) Port of Los Angeles, Los Angeles (CoSMoS v3.0); (f) Port of South Los Santos, Los Santos, RCP 8.5 + storm surge, 3.59 m (2300). Pink shading

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denotes flooded areas in all panels. CoSMoS data: https://doi.org/10.5066/F7T151Q4. Satellite imagery in panels (a), (c), and (e): Imagery © 2026 Esri, Maxar, Earthstar Geographics, and the GIS User Community. Imagery in panels (b), (d), and (f): community satellite image of the GTA V game environment (Somnit, 2020).

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 3.59 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 Geoscience communication and educational potential

Sections 5.1 and 5.2 addressed the first two questions posed in the introduction: whether the Los Santos terrain can support quantitative flood modelling at all, and whether the resulting patterns correspond to independent vulnerability analyses for Los Angeles. The qualitative agreement documented above, across three geographically and functionally distinct districts, is what makes the third question worth asking in the first place. A game terrain that diverged substantially from the real city could still be an engaging teaching prop, but any claim about its value for climate communication would then rest on coincidence rather than on a demonstrated correspondence between fiction and geography. What follows takes that correspondence as its starting point.

The geo-gaming literature distinguishes two pathways through which game worlds contribute to geoscience learning. Facilitated learning describes structured use in a classroom or lab, guided by an educator toward stated objectives; tangential learning describes the self-directed curiosity that follows unplanned exposure to a game world, for example a player noticing an unfamiliar coastline or river delta and later looking up why it looks that way (Squire, 2011; Hut et al., 2019; McGowan and Alcott, 2022). GTA V is unusually well placed for both. Its distribution, more than 225 million copies sold as of August 2025, the second best-selling video game of all time (Take-Two Interactive, 2025), means a large share of secondary and tertiary students already hold a working mental model of Los Santos before any lesson begins. Facilitated learning can build on that existing familiarity rather than construct it from nothing, while tangential learning happens outside any classroom and is not something this paper can measure directly. What we can establish is only its precondition: that the terrain a tangential learner already half-knows is geomorphologically meaningful rather than arbitrary set dressing.

This familiarity matters for reasons that go beyond intuition. Climate change is persistently experienced as psychologically distant, remote in time, displaced to other places, and uncertain in its personal stakes, and that distance is a well-documented barrier to public engagement (Spence et al., 2012). Attempts to close it through visual communication have had uneven success: generic or catastrophic imagery can provoke disengagement as easily as concern, and the choice of image matters nearly as much as the science behind it (Nicholson-Cole, 2005). A familiar, personally navigated virtual landscape closes the distance from an unusual direction: not by showing an audience a real place they may never visit, but by showing them a place many of them already inhabit, repeatedly, by choice. Watching the Vespucci marina one has piloted a boat through, or the Great Ocean Highway one has driven at speed, disappear under a projected sea level turns an abstract number into a recognisable scene without asking the viewer to first imagine themselves into somewhere unfamiliar. Dickey (2007) showed that this kind of personally meaningful context measurably improves learning outcomes in game-based settings; we propose that closing psychological distance is the mechanism behind that improvement here, while acknowledging that this remains a plausible mechanism rather than one we have tested directly in this study.

To move this argument from plausible mechanism to a testable proposal, we designed a six-lesson classroom sequence as part of the underlying thesis (Nörenberg, 2020) and structured it using Klafki's didaktische Analyse, a framework built around five questions an educator should ask of any teaching unit: what does this topic exemplify, why does it matter to students now, why will it matter to them later, how is the material internally structured, and how can it be made accessible (Klafki, 1969). The sequence, summarised in Table 4, was developed for grade 10 (ages 15 to 16) and mapped explicitly onto the official curriculum framework for the German state of Brandenburg, under the content area "climate change and climate protection as an example of international conflict and conflict resolution". Lessons 1 to 3 build the scientific grounding covered in Sects. 2 and 3 of this paper: observed climate change, the greenhouse effect, and the RCP scenario concept, introduced through a cooperative-learning structure of individual work, then paired discussion, then class-wide synthesis, rather than direct instruction alone. Lesson 4 is the practical core: students explore the Los Santos map by helicopter in a modified, age-appropriate build of the game with weapons, blood, and every other vehicle removed, sketch where they expect flooding under the two scenarios developed in Lesson 3, and then reproduce the flood-mapping method of Sect. 3 themselves under teacher guidance, converting the resulting flooded area into a number of football pitches to make the figure tangible. Lessons 5 and 6 turn to mitigation strategies and to the concept of sustainable urban development, using Masdar City as a contrasting real-world case of a purpose-built low-carbon city.

Lesson	**Focus**	**Core activity**
1. Motivation and prior knowledge	Activating what students already know	Group mystery exercise linking a dengue fever case to climate change, followed by a mind map and an anonymous quiz on observed climate change
2. The greenhouse effect and its causes	Natural versus anthropogenic drivers	Greenhouse-vs-control thermometer experiment, paired with contrasting newspaper articles on natural and anthropogenic climate change

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3. Future climate scenarios	RCP storylines and radiative forcing	Comparison of RCP and SRES framings, then paired work developing the RCP 2.6 and RCP 8.5 storylines
4. Mapping sea level rise on Los Santos	The practical GIS exercise	Helicopter exploration of the modified game map, a hand-drawn flood prediction, then a guided reproduction of the flood-mapping method in Sect. 3 using the Lesson 3 scenarios
5. Mitigation strategies	Reducing emissions at global and local scale	Brainstorm of individual actions, jigsaw reading on REDD+ and livestock emissions, class discussion of which strategy matters most
6. Sustainability and the city of the future	Applying the concept to urban planning	Sustainability-triangle worksheet, think-pair-share on sustainable urban planning, case study of Masdar City

Table 4. Overview of the six-lesson classroom sequence developed for grade 10 as part of the underlying thesis (Nörenberg, 2020), structured against Klafki's (1969) didaktische Analyse and aligned with the Brandenburg state curriculum framework.

Several constraints qualify this proposal, and they deserve to be stated as plainly as the opportunity. As implemented in Lesson 4, the exercise depends on a modified build of GTA V with weapons, blood, and explosions disabled and every vehicle removed except the helicopter used for exploration, since the unmodified game carries an 18+ rating in most jurisdictions; without that modification the sequence is not usable below university level. The underlying thesis also flags a subtler limitation worth carrying into the wider argument here: beyond the geomorphological compressions catalogued in Sect. 5.1, the game's social representation is simplified in ways that are easy to overlook, for instance the absence of visibly pregnant characters or parents with strollers among its pedestrians. Asking students to notice this kind of omission, alongside the missing Ballona Creek wetlands or the compressed distance between the marina and the airport, extends the exercise from a lesson in geomorphology into a broader one about what any simulated environment leaves out and why. Familiarity with Los Santos is, in addition, unevenly distributed: console and PC gaming skews toward male, higher-income, and Global North populations relative to the student body as a whole, and an exercise built on existing player familiarity risks widening rather than levelling engagement gaps unless every step, as in Lesson 4, is written to depend only on the supplied map and data rather than on prior gameplay experience. Its pedagogical value lies throughout in the comparison against real vulnerability data in Lessons 3 and 4, not in the game output taken in isolation, and this distinction needs to be made explicit to students and to anyone encountering the approach outside a facilitated setting.

The forthcoming release of Grand Theft Auto VI, set in Leonida, a fictional state modelled on Florida and centred on a detailed recreation of Miami, gives this workflow a natural next test, on both scientific and pedagogical

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grounds. Miami sits on a flat, porous limestone platform that precludes conventional flood barriers, already experiences recurrent tidal flooding, and faces some of the most severe projected sea level rise impacts of any major US city (Wdowinski et al., 2016); the confirmed GTA VI map also includes an Everglades-inspired wetland region whose real counterpart is threatened by saltwater intrusion. Repeating the validation performed here against emerging AR6-based vulnerability assessments for South Florida would test whether greater game realism produces greater geomorphological fidelity. Repeating the classroom sequence outlined in Table 4 with a second, independently developed game world would test something else: whether the educational case made in this section depends on some particularity of GTA V, or generalises to the wider geo-gaming approach we are arguing for. Either test would benefit from the closer collaboration between schools and game developers that the underlying thesis already calls for: a purpose-built educational build, ideally with sea level rise simulated live within the game engine itself rather than mapped afterward in a GIS, would remove the age-rating barrier at its source and let the visualisation respond directly to the scenario a class chooses to explore.

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 of 5.18 m projected for 2300 would inundate 5.1 % of the mapped land area of Los Santos, rendering the port, wastewater infrastructure, and coastal energy facilities non-functional. At the illustrative 2500 horizon (Maribus, 2017), extreme sea levels of 8.22 m would extend inundation to 6.5 % of land area, leaving the beach near Fort Zancudo as the only substantial coastal strip above water. Under the mitigation scenario RCP 2.6, inundation at 2300 is limited to 2.2 % of land area with no major infrastructure threatened, vividly 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.

Third, and central to this paper's contribution, we set out a concrete case for using this workflow in geoscience communication and education: a grounding in facilitated and tangential learning and in the psychological-distance literature on climate risk perception, a fully designed six-lesson classroom sequence built around Klafki's didaktische Analyse and aligned with an official state curriculum (Table 4), and an explicit account of the legal, demographic, and representational constraints any implementation would need to address. The evidentiary basis for this claim is the correspondence documented in Sect. 5.2: familiarity with Los Santos would not by itself justify using the game for climate communication if its flood behaviour bore no relationship to the real city it depicts.

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We recommend the approach as a template for geoscience communication using open-world video game environments, with the explicit caveat that the AR5 scenarios used here should be updated to AR6/SSP projections in future work, and that the bath-tub inundation model and its limitations be communicated transparently to all audiences. 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 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. 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 (NOAA, 2020a). The processed raster DEM and ArcGIS model builder file are available from the corresponding author upon reasonable request.

Supplement

The Supplement (Figs. S1–S4) contains full-island flood extent maps for all four scenario/storm-surge combinations at the three time horizons presented in this study. The georeferencing control points and shoreline determination points are shown in Fig. 2 of the main text.

Author contributions

PN designed and conducted the GIS analysis and performed all flood simulations. HL supervised the study, contributed to validation, interpretation of results, and the geoscience communication framing, and wrote the initial manuscript draft. Both authors approved the final version.

Competing interests

The contact author has declared that neither of the authors has any competing interests.

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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