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Analysis of Extreme Coastal Water Levels along the South American Pacific Coast and their interaction with Vertical Land Motions

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INTRODUCTION

South American Pacific coasts (SAPC) behavior is subjected to oceanographic and tectonic conditions and those triggered by anthropogenic and climate change. Uncertainty about Extreme Coastal Water Levels (ECWL) behavior in historical and future conditions remains high worldwide. Studies analyzing ECWL along the South American Pacific Coast (SAPC) are scarce and challenging, as they are used to develop coastal planning and address possible hazards and their countermeasures. Vertical Land Motions (VLM) produced by tectonics along the SAPC are generated because of Nazca plate subducting beneath the South American plate and can produce secular uplift/subsidence of about 1 to 10 mm/yr comparable with sea level rise rates. This study aims to comprehend the historical and future ECWL and their projections along the SAPC, interacting with VLMs produced by tectonics.

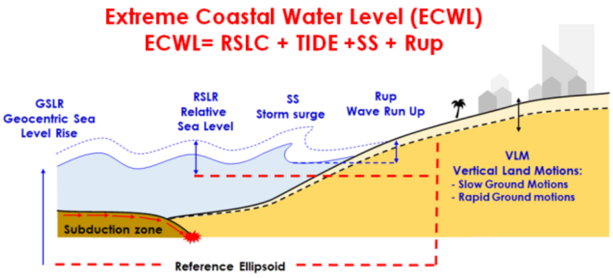

Figure 1:Vertical interaction between ECWL and VLM

DATA

The historical period combines measurements and numerical modeling data. OSU-TPXO model was used to obtain the AT, sea level anomalies (SLA), and absolute dynamic topography (ADT) from Copernicus satellite data. Climatological indexes (CI) (SOI, PDO, SAM, etc.) were selected from NOAA. JRA-55 reanalysis was used to obtain SS and waves hindcast for the 1959-2019 and 1979-2019 periods, respectively. Foreshore slope values obtained from the CoastSat website were used to obtain Rup2%. A tide gauge (TG) and wave buoy measurements along the Chilean coast were obtained from the Hydrographic and Oceanographic Service from Chile (SHOA in their Spanish abbreviation). CMIP-6 Data was used to obtain regional projections of SLR and VLM.

The seamless experiment was considered to obtain the storm surge and wave future for ECWL estimation (Shimura et al., 2022). This continuously considered the climate simulation from 1950 to 2099. Storm surge was obtained from global simulations conducted with the unstructured grid model ADCIRC, forced by hourly sea surface winds, sea level pressure, monthly SIC, and wave projections for the wave run-up obtention in the same period.

METHODOLOGY

ECWL along the SAPC were obtained following the expression in Figure 1. Measurements are available to validate some ECWL components variables, allowing us to define our historical period from 1993 to 2019. Individual components were analyzed hourly to understand their variability, contributions, and trends through different periods. AT was obtained every 0.5° from 0° to -60°. Comparison between wave hindcast data and buoy measurements located among the -18° to -45°was conducted, and once validated, was used to obtain Rup2% with Stockdon et al. (2006). For the historical period, VLMs were obtained in TG stations in the SAPC by merging ADT and TG measurements (Cazenave et al., 1999), while the projections were obtained from CMIP-6 data. Once obtained, they were compared with ECWL trends in the same positions. Average relative contribution (ARC) for the top 5% events to understand the changes in the ECWL between the historical and future conditions, was obtained as mean(AT)/mean(ECWL)+mean(SLA)/mean(ECWL)+ mean(storm surge)/mean(ECWL)+mean(Run-up)/mean(ECWL) =1x100.

RESULTS

Historical ECWLs for the 1993-2019 period combine measurements and numerical modeling. ECWL variability shows values over 5 m with a median value of 2.58 m ± 092 m, with trends strongly influenced by sea level anomalies, while R2% is the main contributor. Projections obtained (2020-2100) reveal changes in wave characteristics variability affecting R2% and RSLC of about 0.5 to 1 m (medium confidence).

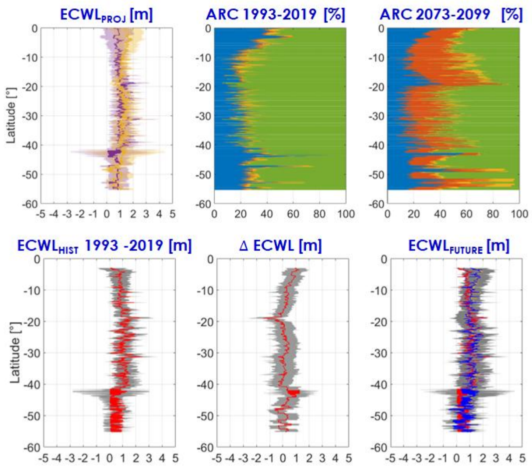

Figure 2: Superior panel shows the average relative contribution of ECWL projections. Bottom panel shows the historical ECWL, the changes in the ECWL And the future behavior

Historic VLM obtained by combining tide gauge and satellite data reveals that trends of secular uplift/subsidence due to tectonics effects in tide gauge positions are larger than CMIP-6 projections for the 2005-2020 period, however, it also change faster than those obtained for the ECWLs.

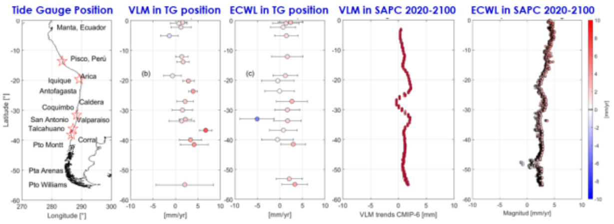

Figure 3: Trend comparison between VLM and ECWL for both historical period, and future projections along the SAPC.

CONCLUSIONS

ECWL 27-year hindcast obtained along the SAPC shows median values of 1.0 to 1.5. m with maximum median values of 2.5 m. When the superior 5% is analyzed, run-up 2% is the main contributor among the variables for reanalysis (60% to 70%) and projections (median value of 38%). Projections analyzed show that relative sea level (RSL) and median values of the relative contribution will vary between 25% and 35%. Storm surge contribution along SAPC in historical and projections analyzed are minor, at 5% to 10%.

VLM trends obtained for historical and future projections are similar in magnitude to those obtained for the ECWL. When the coseismic displacements are included in the analysis, the rates will be much higher than those obtained from ECWL.

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