# storm surges & climate change in eastern Victoria, Australia

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The inevitability of rising mean sea levels due to global warming accompanied by possible changes to weather patterns that drive sea level extremes such as storm surges indicate that coastal communities and assets along the eastern Victorian coast will increasingly come under threat from coastal flooding. This study combines various modelling and statistical techniques to explore the effect of climate change on extreme sea level along this coastline.

## Approach

### Data and event selection

Victorian tide gauge records were filtered to remove the tidal signal to yield records of "sea level residual". Complete sea level residual records for the period 1966-2003 were obtained for two gauges by using an analysis of neighbouring records to fill data gaps. A threshold exceedance method was used to identify 489 storm surge events that occurred in the 38 year period. The events selected ranged in duration from 2 to 11 days.

### Hydrodynamic modelling

Each event was simulated using the hydrodynamic model GCOM2D (Hubbert and McInnes, 1999) on a 1 km grid covering the region shown in Figure 1. Simulations at 100 m over Corner Inlet and 50 m over the Gippsland Lakes were also undertaken using the 1 km simulations for boundary conditions. Surface wind and pressure fields required by the model were obtained from 6-hourly NCEP reanalyses interpolated to the model grid.

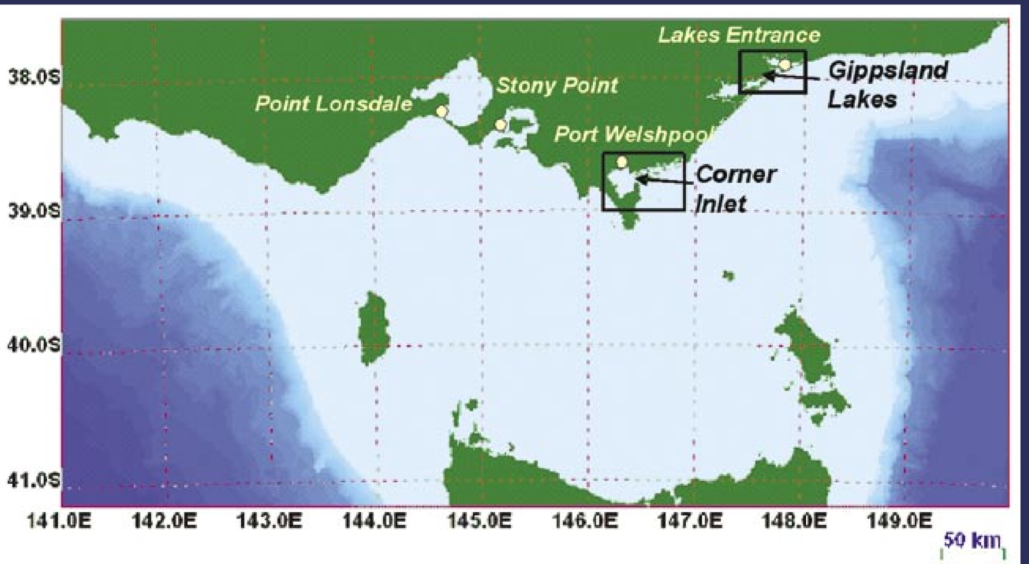


Figure 1: The coverage of the 1 km storm surge model grid.

### Storm surge return periods

For each model grid box probabalities of occurrence and return periods for surge heights were estimated by fitting a Generalised Extreme Value distribution to the model output. Distribution parameters were estimated from the four largest peak storm surge heights per year using the maximum likelihood method.

### Combining with tides

Total sea levels were evaluated by summing the surge and tide heights that were randomly sampled from the respective probability distributions. Owing to the predominantly semi-diurnal tides and the typically multi-day duration of the storm surge events, distributions were developed for high tides across the region. Where tide gauge data was not available, GCOM2D was used to simulate the tides across the region with the tide heights specified on lateral boundaries of the model using global tidal constituents. The modelled tides were then analysed to produce higher resolution tide constituents, which in turn were used to predict the tides and develop frequency distributions for the high tide values (Figure 2).

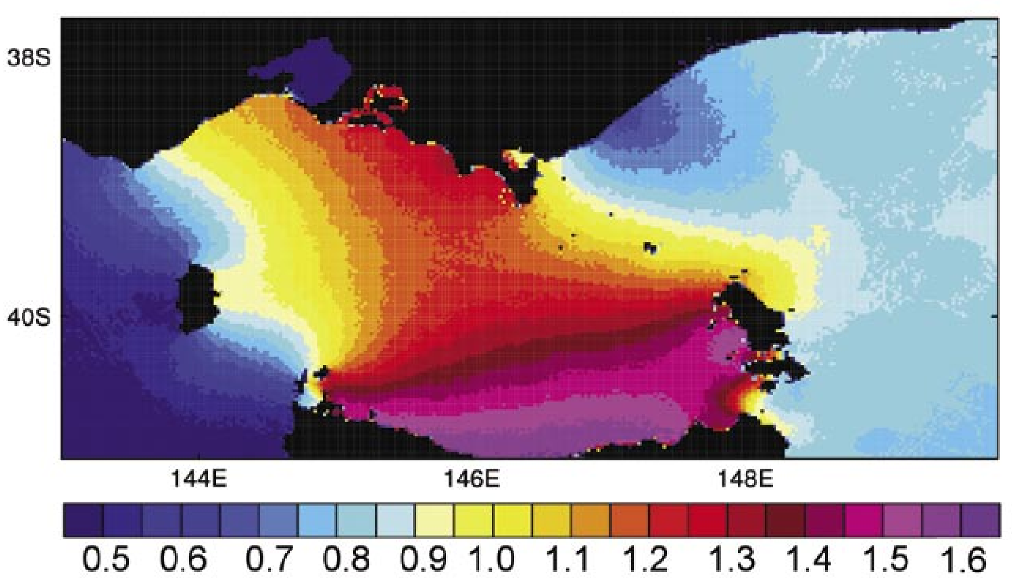


Figure 2: The spatial pattern of high tide across Bass Strait.

## Meteorological drivers of storm surge

Synoptic typing of the weather patterns associated with surges of at least 0.4 m at Lakes Entrance revealed that 70% of storm surges were due to cold fronts, 23% were due to Tasman lows and 6% were due to east coast lows (Figure 3). At Stony Point on the other hand, almost 100% of events were due to cold fronts.

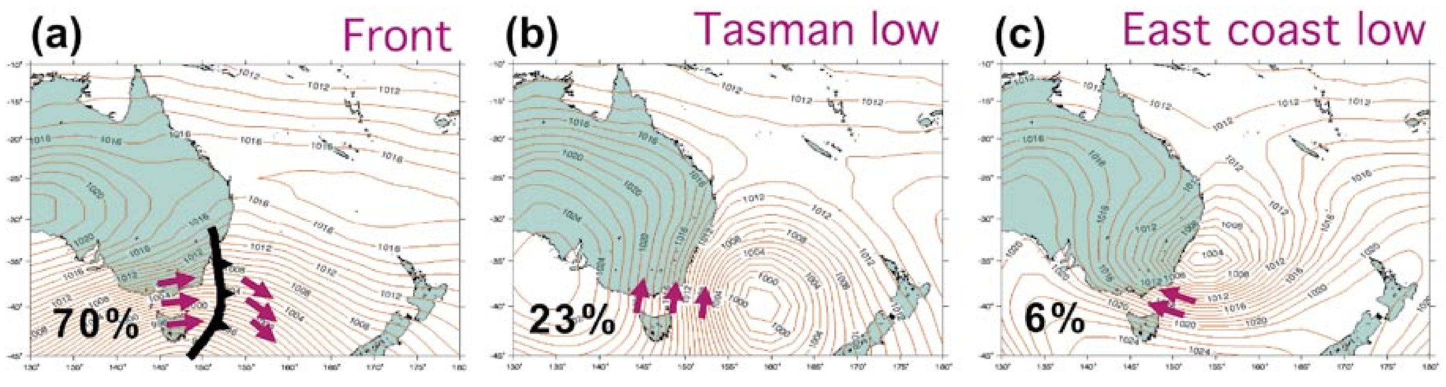


Figure 3: Weather events responsible for extreme sea levels.

## Climate change scenarios

Projections of future wind speed changes were developed from an analysis of thirteen different climate models using the pattern scaling technique of Whetton *et al*. (2005) in which the wind speed is regressed against its globally averaged warming signal. The spatial patterns of change from all thirteen models are used to establish ranges of possible change for the region of interest. These are combined with IPCC projections of temperature change under the SRES emissions scenarios to provide percentage wind speed changes for 2070 for average and 95th percentile wind speeds. These changes, which are summarised in Table 1, were applied as a perturbation to the reanalysis wind fields.

Table 1: Projected annual and winter wind speed changes for Bass Strait as a percentage relative to average wind speeds for 1961 to 1990.

| Season | Mean wind speed 2070 | | | 95th Percentile wind speed 2070 | | |
|---|---|---|---|---|---|---|
| | Low | Mid | High | Low | Mid | High |
| Annual | -5 | 3 | 10 | -6 | 3 | 11 |
| Winter | -4 | 5 | 14 | -6 | 7 | 19 |

## Results

The present climate 100 year storm surge pattern (Figure 4) indicates that higher sea levels occur further east. The 1 in 100 year storm tide for Corner Inlet in 2070 (Figure 5) shows inundation in the range of 0.4 to 1.2 m occurring along parts of the coastline. The increase in the area of inundation from the current climate 100 year event at Ports Franklin, Welshpool and Albert are 0.7, 0.4 and 0.5 km² respectively.

The inundated area for the 100 year event over the Gippsland Lakes increases from 25 km$^2$ to 66 km$^2$ in the 2070 scenario shown. Extensive inundation of a dry lake system situated between the lakes and the open coastline near Loch Sport can be seen.

The current climate storm tide values obtained in this study compare reasonably well with those from an earlier study by Tawn and Mitchell (1990) where a GEV distribution was fitted to sea level data from tide gauges. This indicates that the modelling approach used here yields reasonable estimates of the spatial variation in storm tide. Under the 2070 scenarios, worst case wind speed increases have a smaller effect on extreme sea levels than mean sea level rise.

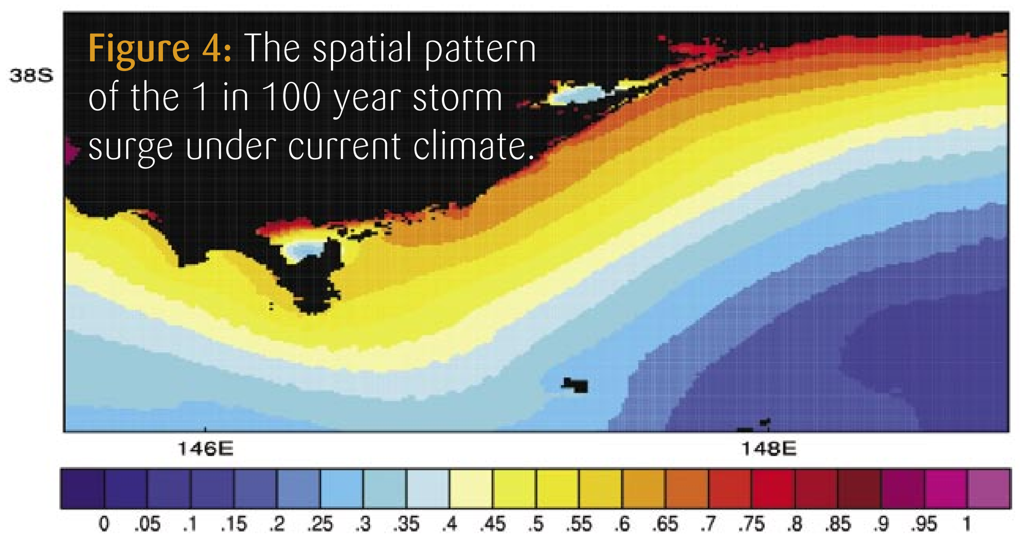


Figure 4: The spatial pattern of the 1 in 100 year storm surge under current climate.

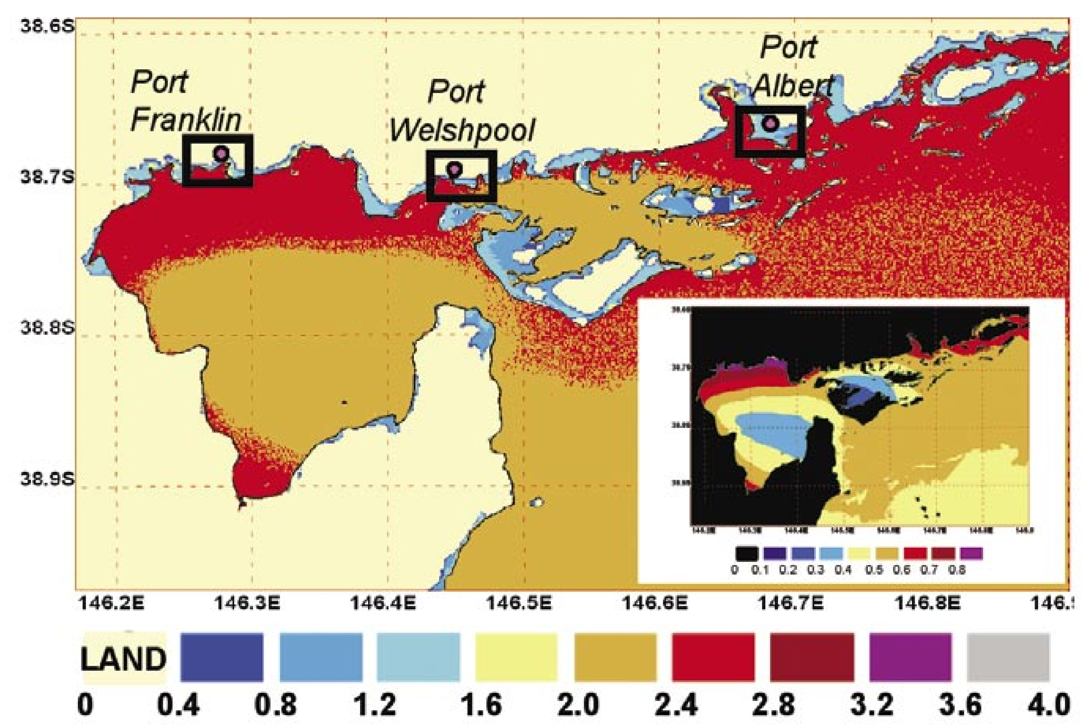


Figure 5: The current climate 100 year storm surge (inset) and the 2070 storm tide with 10% increase in winds and 0.49 m mean sea level rise.

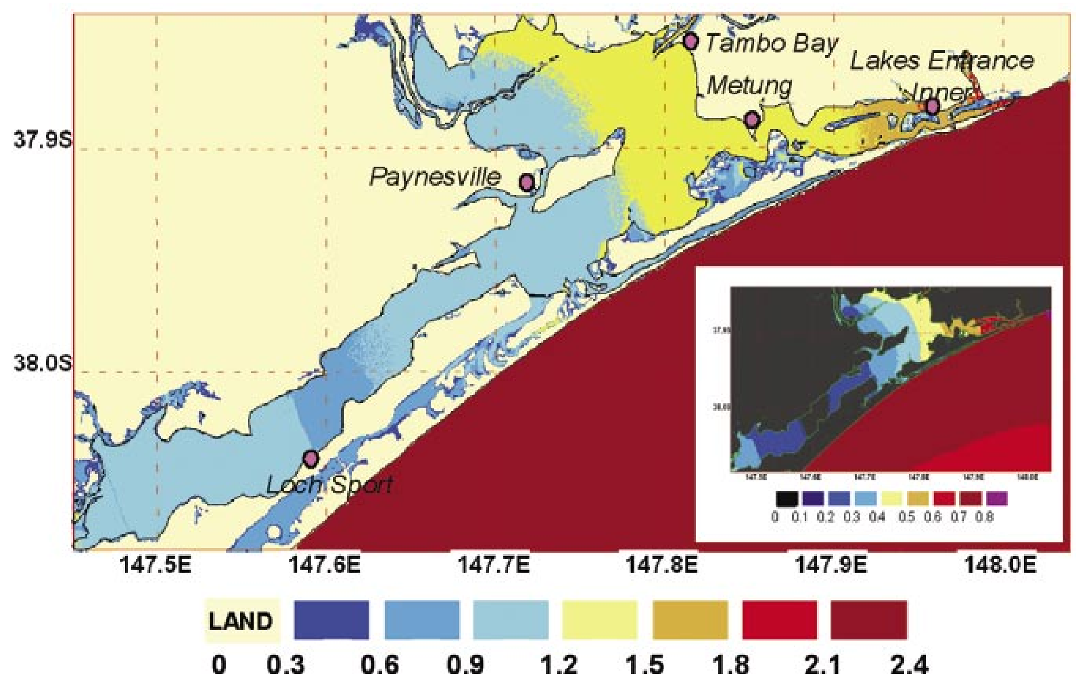


Figure 6: The current climate 100 year storm surge (inset) and the 2070 storm tide with 10% increase in winds and 0.49 m mean sea level rise.

Table 2: Selected storm surge and storm tide values in metres. Numbers in blue are the difference between the particular scenario value and the control value.

| Location | 100 year surge level | 100 year storm tide | Tawn and Mitchell (1990) | 100 year storm tide 2070 high | 100 year storm tide 2070 high + slr (49cm) |
|---|---|---|---|---|---|
| Stony Point | 0.71 | 2.08±0.07 | 2.08±0.07 | 2.13 (0.10) | 2.62 (0.49) |
| Port Welshpool | 0.54 | 1.65±0.06 | 1.60±0.07 | 1.72 (0.07) | 2.22 (0.49) |
| Lakes Entrance | 0.71 | 0.98±0.06 | 0.96±0.04 | 1.07 (0.09) | 1.56 (0.49) |

## Summary and future work

- Mean sea level rise will have the dominant effect on changes to extreme sea levels.
- Even under a low wind speed change scenario (i.e. a reduction in wind speed), a low scenario of mean sea level rise will cancel out any reductions in sea level extremes due to reduced storm surge heights.
- Land subsidence due to offshore oil and gas extraction and long term erosion may increase the risk of inundation along the eastern Victorian coastline.
- The impact of coincident events (e.g. high rainfall and winds) may also increase in the future.

### References

Hubbert, G. D., and K. L. McInnes, 1999: A storm surge inundation model for coastal planning and impact studies., J. Coastal Research, 15,168-185.

Tawn, J. A. and Mitchell, W. M. 1990: A spatial analysis of Australian extreme sea levels. Unpublished manuscript.

Whetton, P. H., K. L. McInnes, R. N. Jones, K. J. Hennessy, R. Suppiah, C. M. Page, J. Bathols, P. J. Durack 2005: Australian climate change projections for impact assessment and policy application: A review. CSIRO technical report. 34 pp. http://www.cmar.csiro.au/e-print/open/whettonph_2005a.pdf.

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