



Extreme Wave and Coastal Hazard Projections in the North Indian Ocean



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Introduction

- Waves drive shoreline change, sediment transport and the stability of coastal infrastructure along one of the world's most densely populated coasts.
- North Indian Ocean (NIO) waves are monsoon-driven; coarse global projections miss nearshore detail.
- Aim: project changes in extreme waves and coastal hazards along the NIO coast.

Data and Methodology

- 8-member CMIP6-forced WAVEWATCH III ensemble, ~6.8 km × 9.5 km coastal grid
- Historical 1985–2014; future 2041–2070 and 2071–2100; SSP1-2.6 and SSP5-8.5
- Extremes: Peaks Over Threshold (95th percentile) with a Generalized Pareto Distribution (GPD)

GPD (exceedances $y = x - u$)

$$F(y) = 1 - (1 + \xi y / \sigma)^{-1/\xi}, \quad \xi \neq 0$$

$$F(y) = 1 - \exp(-y/\sigma), \quad \xi = 0$$

defined for $y \geq 0$, when $\xi \geq 0$, and

$$0 \leq y \leq -\sigma/\xi, \text{ when } \xi < 0$$

σ is scale parameter ($\sigma > 0$), and

ξ is the shape parameter

T-year return level

$$RL_T = u + (\sigma/\xi)[(\lambda T)^\xi - 1], \quad \xi \neq 0$$

$$RL_T = u + \sigma \ln(\lambda T), \quad \xi = 0$$

$$\Delta H_s^{50yr} = RL_{50,future} - RL_{50,historical}$$

u : threshold, σ : scale, ξ : shape, λ : mean annual number of independent exceedances, T : return period

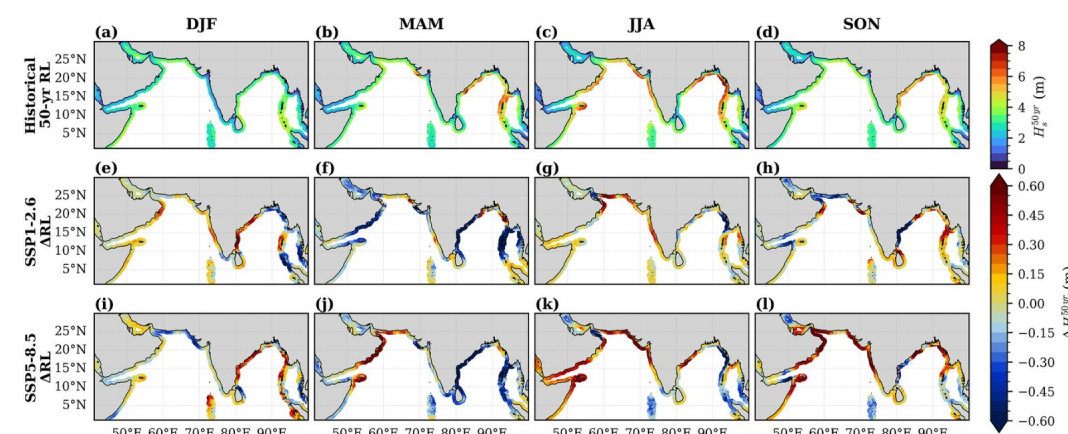
$$CCHI = w_{sev} \cdot R_{sev} + w_{exp} \cdot R_{exp}$$

percentile ranks of severity (ΔH_s^{50yr}) and coastal exposure (distance to shore)



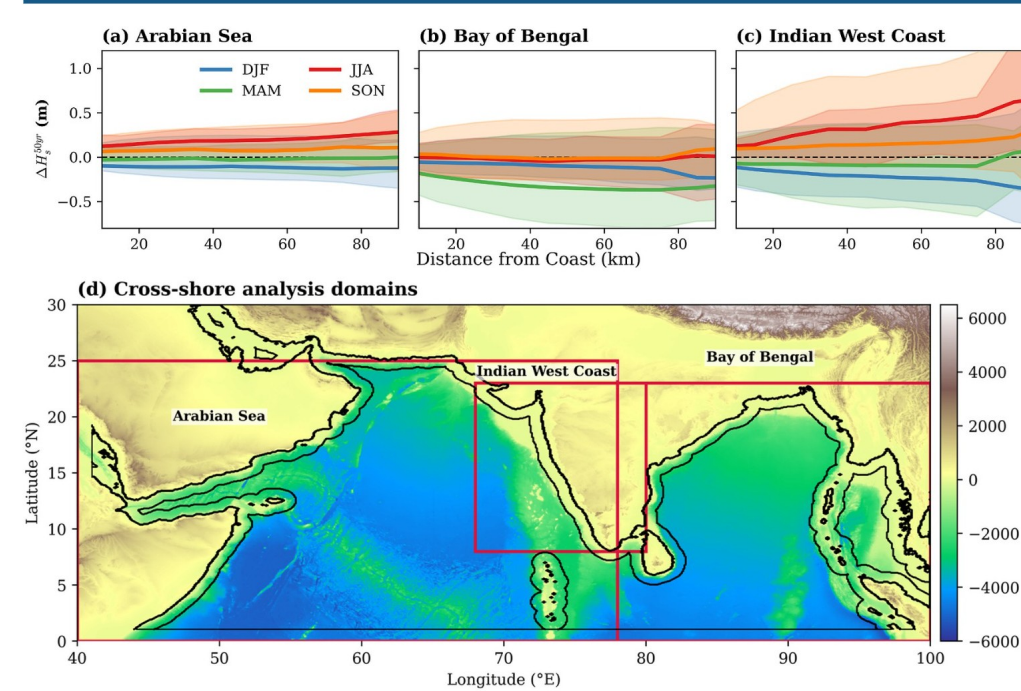
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50-Year Return Level of H_s



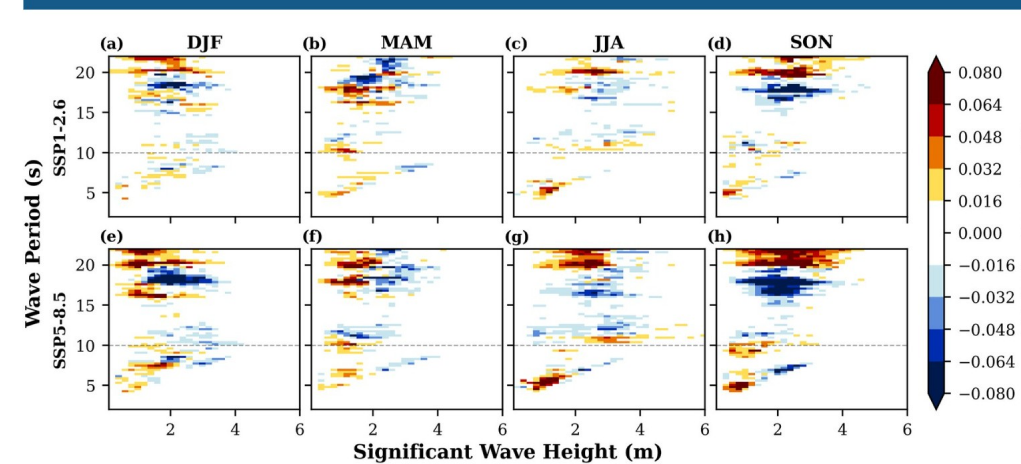
- Historical 50-yr return level of H_s (top) and change under SSP1-2.6 (middle) and SSP5-8.5 (bottom), 2071–2100.

Cross-Shore Variation



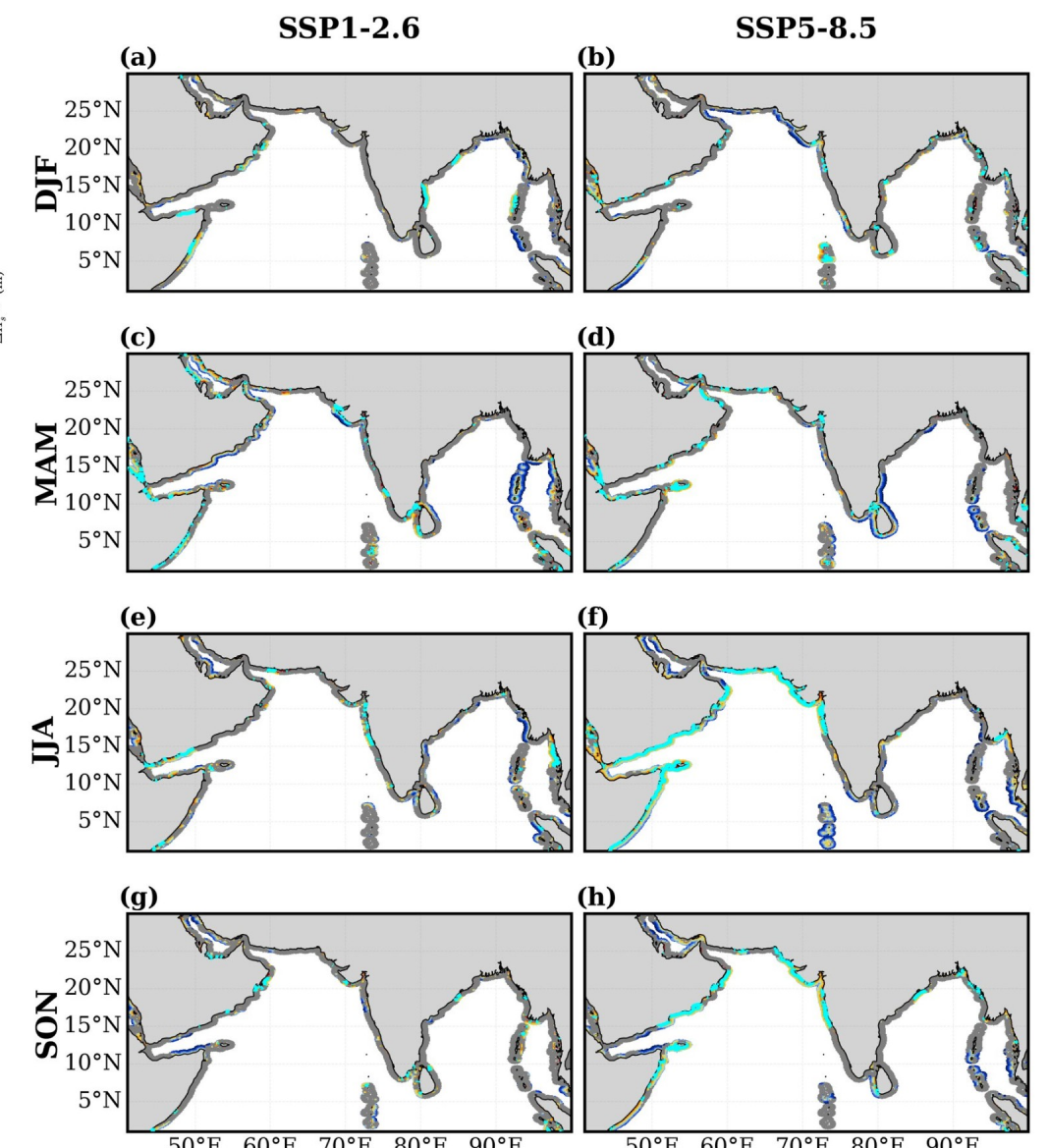
- Change in 50-yr return level with distance from the coast (SSP5-8.5). Line: ensemble median; shading: 10th–90th percentile.

Sea-State Redistribution



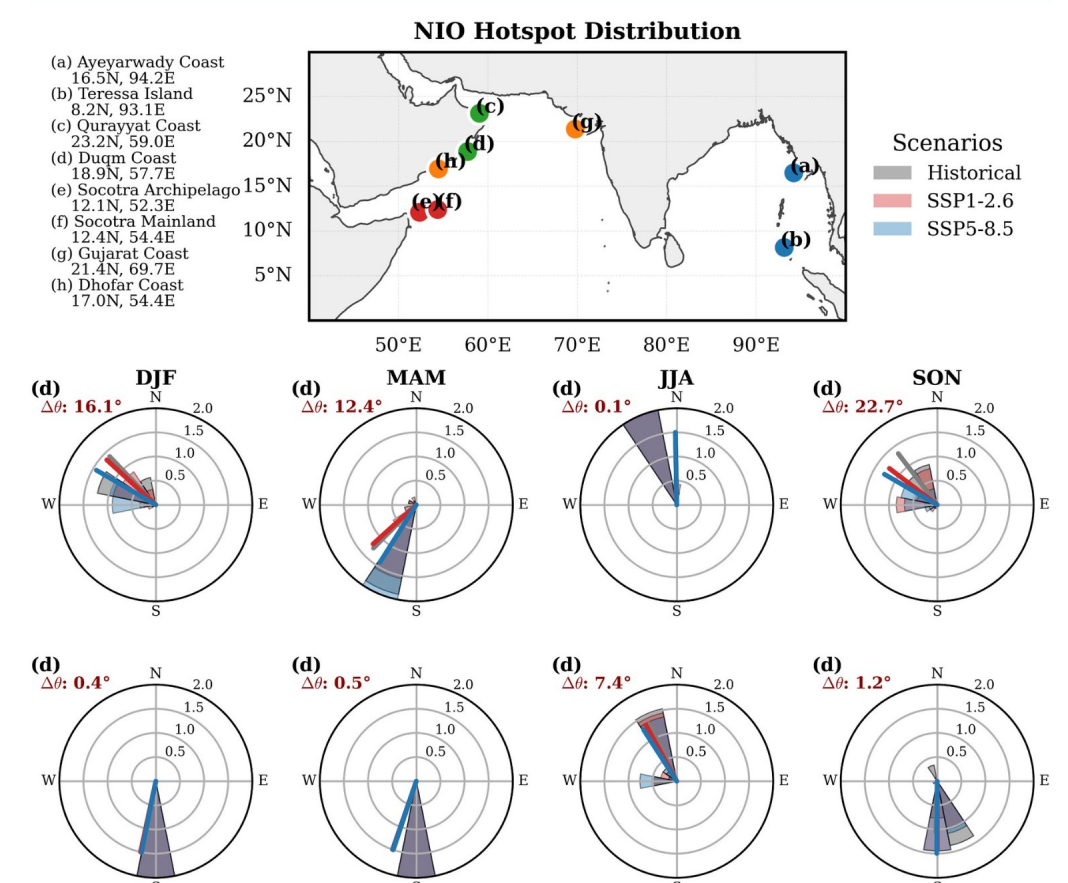
- Change in joint $H_s, \max-T_p, \max$ density relative to 1985–2014: SSP1-2.6 (top), SSP5-8.5 (bottom).

Coastal Hazard Hotspots



- Hotspots for 2071–2100. Gray: low model agreement or below threshold.

Wave Direction at Hotspots



- Hotspot locations and wave roses of seasonal maximum direction

Conclusions

- Under SSP5-8.5, 50-yr return levels of H_s increase by up to 0.60 m (7–12%) along the Arabian Sea and west Indian coast.
- Peak periods lengthen (up to ~1.3 s) and wave directions rotate by up to ~30°.
- Hazard hotspots expand along the west coast of India in the monsoon season.

References

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