2nd International Workshop: Waves, Storm Surges & Coastal Hazards

10–15 November 2019

Melbourne, Australia

INVESTIGATING THE RELIABLE EXTREME WAVE HEIGHT ESTIMATION METHOD FOR INDIAN TERRITORIAL WATERS

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Overview of Presentation

- Extreme wave analysis
- Motivation & Objectives
- Methodology
- Significant wave height data details
- Extreme value estimation methods
- Analysis of results
- Application of statistical methodology
- Conclusions

Extreme wave analysis

- First step in designing a maritime structure is the selection of the design wave.
- Coastal structure design is often proportional to H_D^2 and H_D^3
- Estimation of appropriate extreme wave height ensures:
  - level of protection
  - scale of investment

Motivation & Objectives

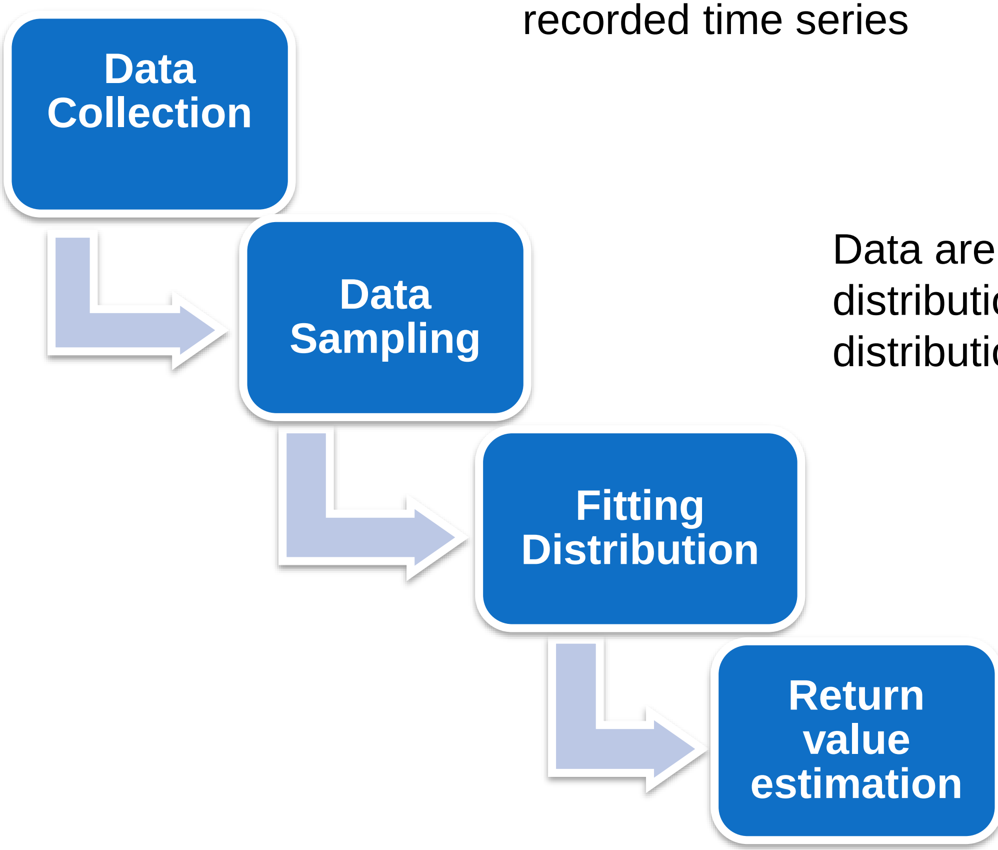
- Establish a general and reliable model for estimation of extreme statistics in Indian waters

- Different estimation methods are employed to obtain return values are:
  - Generalised extreme value distribution (GEV) method
  - Generalised Pareto distribution (GPD) method
  - Polynomial approximation (P-app) method

- Introducing a statistical approach to validate the reliability of return values by considering variability criterion as observed maximum value in the recorded time series

- Develop 100 year extreme wave map for the Indian territorial waters

Methodology of extreme wave analysis



Accuracy depends on the length and quality of the recorded time series

Data are analyzed in a form of cumulative distribution to be fitted to some theoretical distribution function.

Extrapolating the distribution function to the level of probability corresponds to a given period of years

Significant wave height (*H_s*) data

- Buoy measurements are the **most reliable** but at a particular location of interest the buoy data available is **usually small, and often there will be no data**.
- **Data Used:** European Centre for Medium-Range Weather Forecasts (ECMWF), **ERA-interim wave hind cast data** covering a period of **36 years (1979-2014).**
- **Reasons:**
  - **Regular coverage the whole World Ocean**
  - **Long and regular continuous series**, which is important for the statistical aims of extreme value analysis.

Data Details

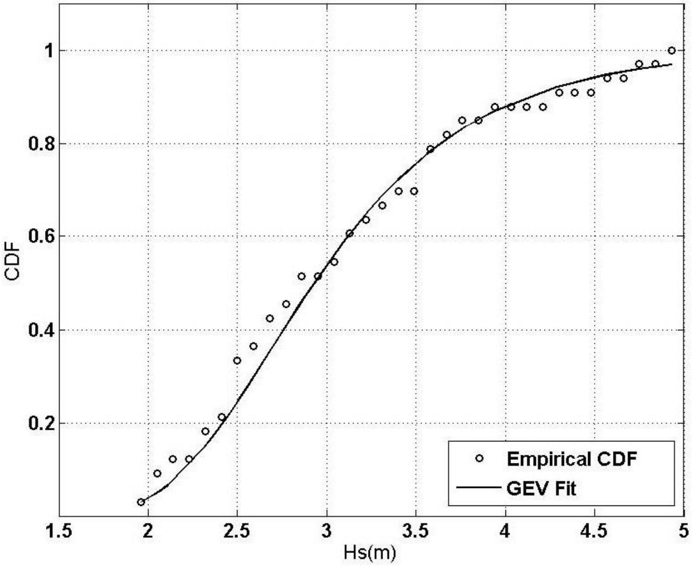
Data Point	Coordinates	Availability	Interval (Hr)	No. of data points
ERA IN-1	19.50N, 85.75E	1979-2014	6	52596
ERA IN-2	15.50N, 81.00E	1979-2014	6	52596
ERA IN-3	10.25N, 75.75E	1979-2014	6	52596
ERA IN-4	14.50N, 73.50E	1979-2014	6	52596
NDBC 44005	43.204N, 69.128W	1979-2014	1	254221
ERA 44005	43.25N, 69.125W	1979-2014	6	52596
NDBC 46050	44.656N, 124.526W	1991-2014	1	180231
ERA 46050	44.625N, 124.50W	1991-2014	6	35064
RON Alghero	40.548N,8.107E	1989-2008	3	125443
ERA Alghero	40.5N,8.125E	1989-2008	6	29220

Generalised extreme value distribution method

Cumulative distribution function

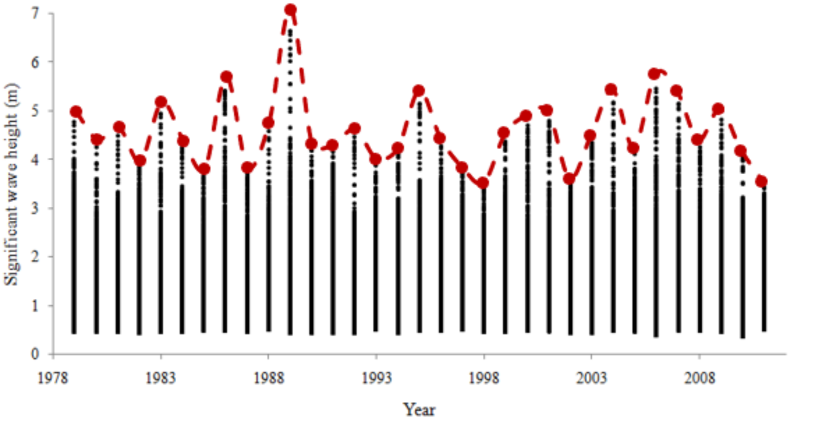
$$GEV(H;\mu,\sigma,\xi)=\begin{cases}\exp\left(-\left(1-\xi\left(\frac{H-\mu}{\sigma}\right)\right)^{\frac{1}{\xi}}\right), & \text{for } \xi\neq 0\\ \exp\left(-\exp\left(\frac{-(H-\mu)}{\sigma}\right)\right), & \text{for } \xi=0\end{cases}$$

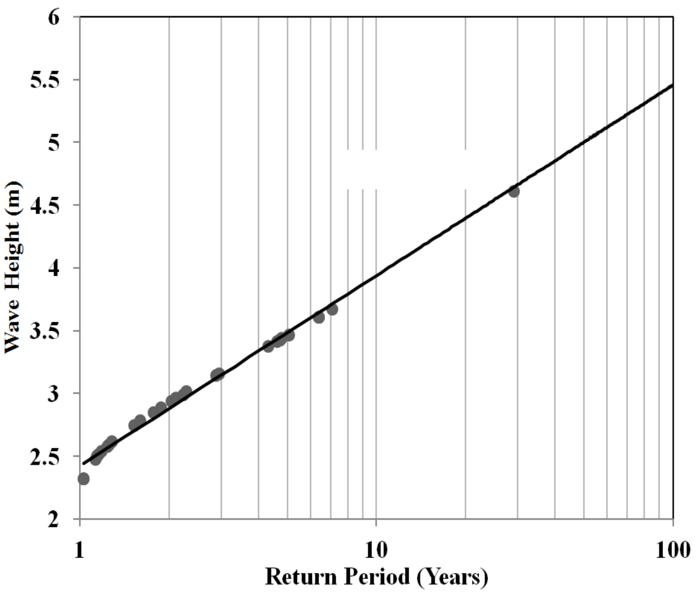
μ, σ and ξ represent the location, scale and shape parameters



Extreme wave height *(H_R)* corresponding to different Return period *(N_R)* $H_R = F^{-1}\left(1-\frac{1}{N_R}\right)$

Annual maxima sampling method $M_n = max\{X_1, \ldots, X_n\}$



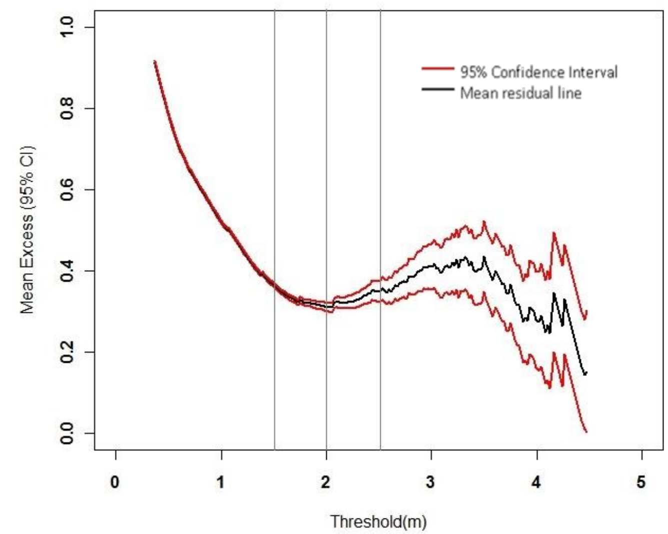


Generalised Pareto distribution method

Peak over threshold sampled data

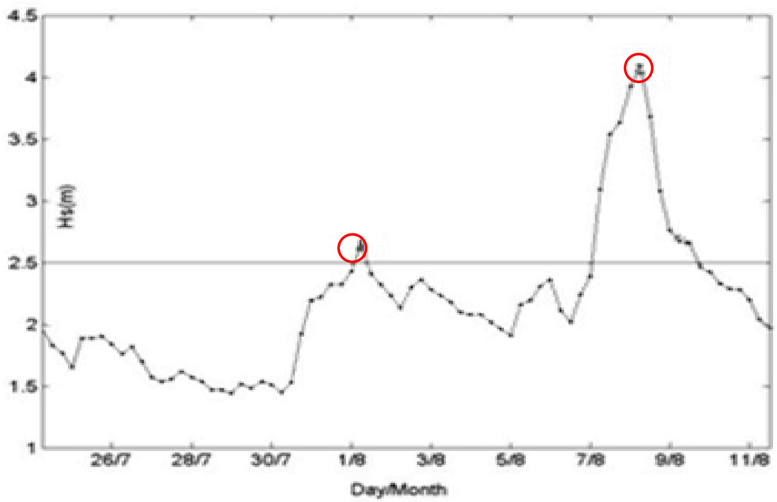
$$GPD(H;\mu,\sigma,\xi)=\begin{cases}1-\left(1-\xi\left(\dfrac{H-\mu}{\sigma}\right)\right)^{\frac{1}{\xi}}, & \text{for } \xi\neq 0\\[2ex] 1-\exp\left(-\left(\dfrac{H-\mu}{\sigma}\right)\right), & \text{for } \xi=0\end{cases}$$

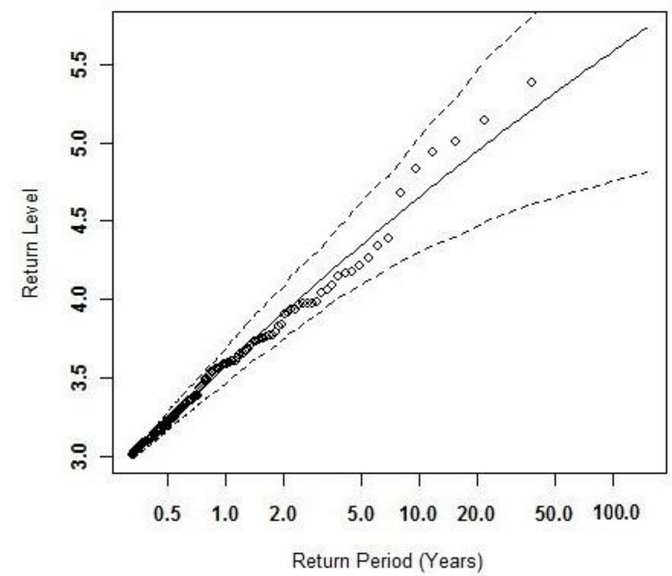
where μ, σ and ξ represent the threshold, scale and shape parameters.



Too low a threshold leads to bias
Too high a threshold will generate fewer excesses, leading to high variance

To ensure the meteorological independence of each storm, cluster maxima at a interval <48 hr apart is considered as the same storm



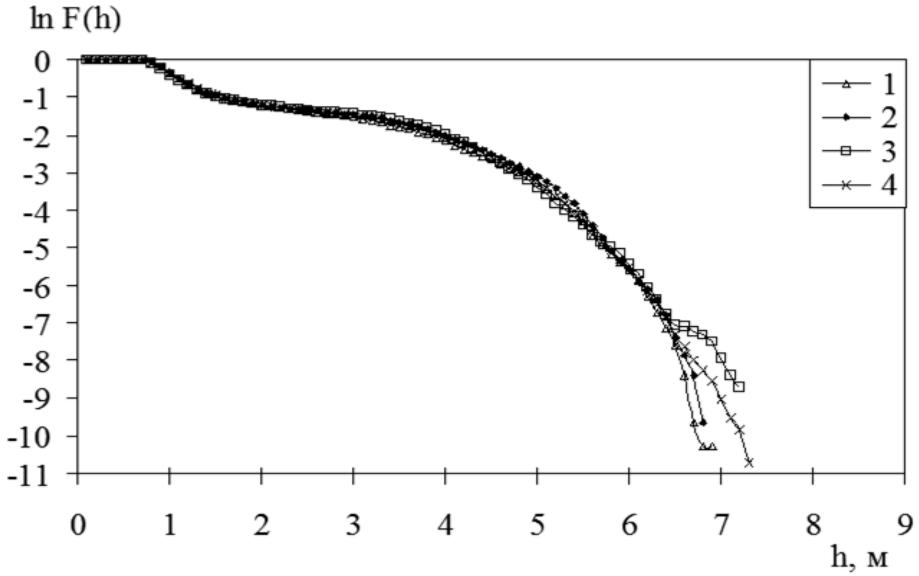


GPD method is preferable in the locations of multiple storm events in a single year

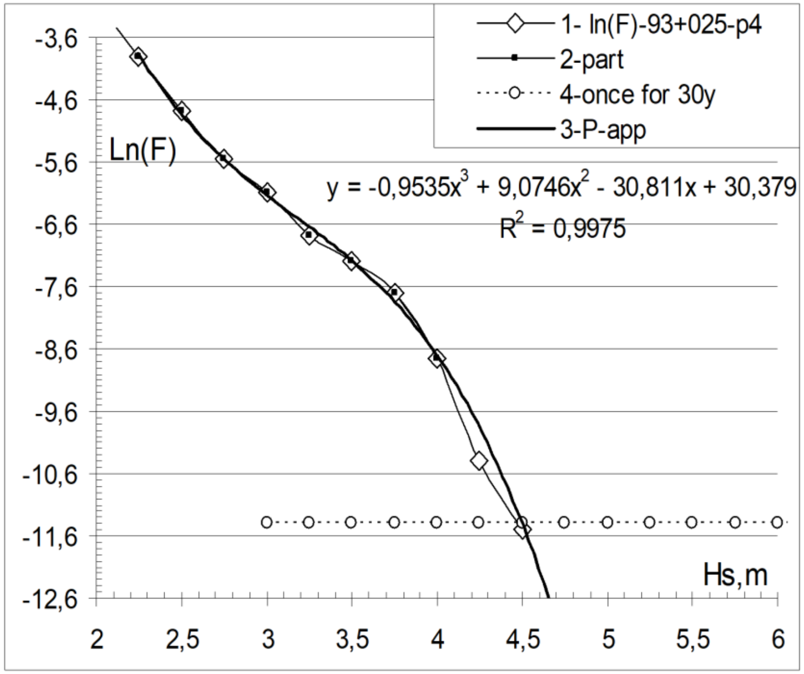
Polynomial Approximation method

Sample: Entire time series of H_s

1. Selection of the statistically reasonable period of a time series for *h.*
2. Estimation of the probability provision function $F(W) = 1 - \int_0^W P(W)dW$
3. Extrapolation of the function *F*(*h*) obtained on the basis *polynomial approximation.*
4. Getting return values $F(W_R) = \Delta t / 8760 . N_R$



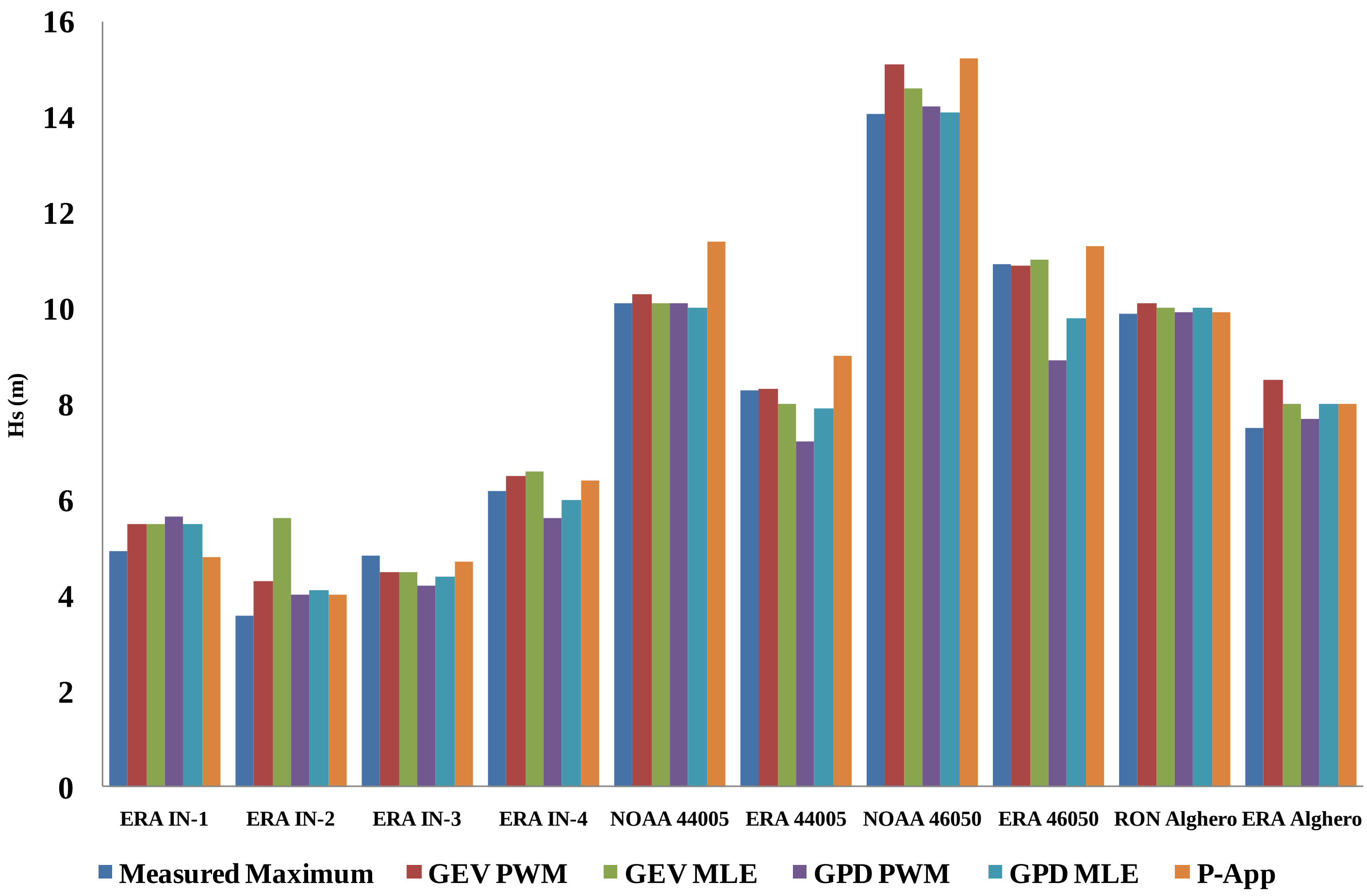
lines 1,2 and 3: three different 10-years parts of 30-years series
line 4 - whole 30-years series



2- points used for approximation
3- line of P-approximation

The bottom level is probability once for 100 years

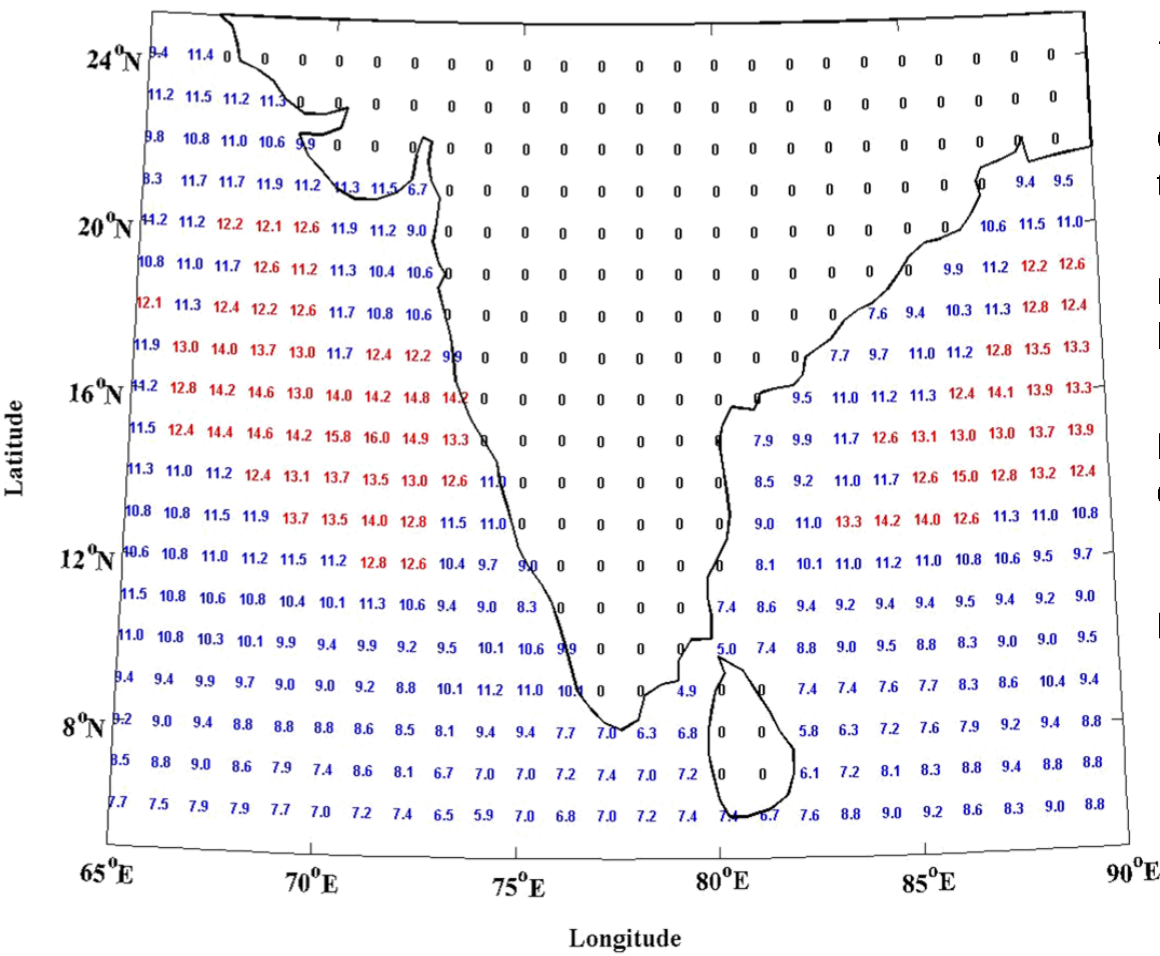
Comparison of 100 year return values from different estimation models



Variation of 30,100 yr return values from observed maximum H_s (%)

Data	GEV				GPD				P-App	
	PWM		MLE		PWM		MLE			
	30-yr	100-yr	30-yr	100-yr	30-yr	100-yr	30-yr	100-yr	30-yr	100-yr
ERA IN-1	-2	12	-2	12	0	15	-2	12	-6	-2
ERA IN-2	-3	20	14	56	-8	11	-5	14	0	11
ERA IN-3	-17	-7	-17	-7	-19	-13	-15	-9	-5	-3
ERA IN-4	-9	5	-11	7	-17	-9	-11	-3	-4	4
NOAA 44005	-5	2	-6	0	-6	0	-7	-1	5	13
ERA 44005	-12	0	-13	-3	-21	-13	-15	-4	-4	9
NOAA 46050	-2	7	-5	4	-12	1	-12	0	0	8
ERA 46050	-9	0	-9	1	-27	-19	-18	-10	-7	3
RON Alghero	-1	2	-2	1	-5	0	-4	1	-7	0
ERA Alghero	0	13	-1	7	-12	3	-8	7	1	7

100 year Extreme wave map



$1^0 \times 1^0$ spatial resolution data

Grid of 21 × 26 = 546 data points covers the area

Bounded by latitudes 5^o N and 25^o N, longitudes 65^o E and 90^o E

ERA-Interim wave hindcast data covering a period of 36 years

Polynomial approximation method

Conclusions

- Drawback of the GEV and GPD methods: forecast extremes smaller than ones observed already
- P-app method shows consistency in estimated return values for both simulated and buoy wave height datasets
- In spite of the continuous variations of sea states over time, the return values for extreme waves can be considered as stationary if the average boundary conditions (e.g., average atmospheric pressure, average wind, average temperatures, etc) remain stationary.

Thank You