



# Properties of an ensemble of projections of extreme water levels near Tallinn

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# Background



**Extreme value estimation is mostly very sensitive to the underlying data and estimation method**

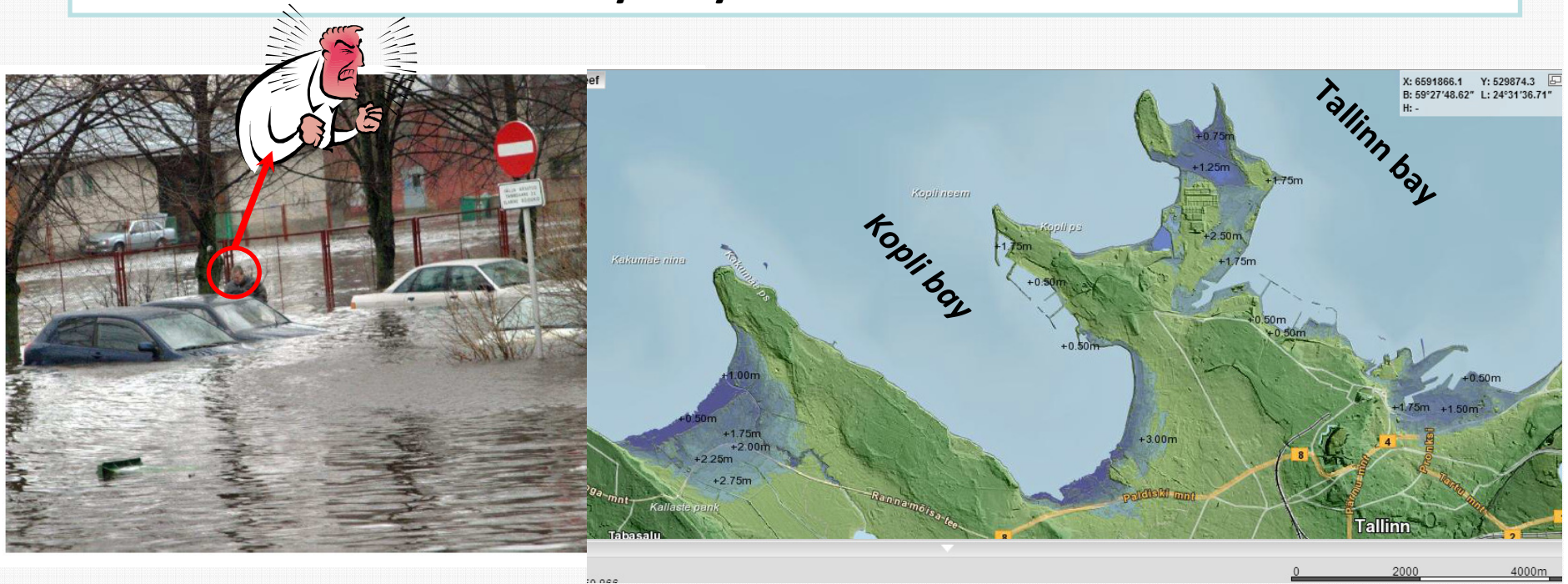
**Difficult to choose the best set of data and method**



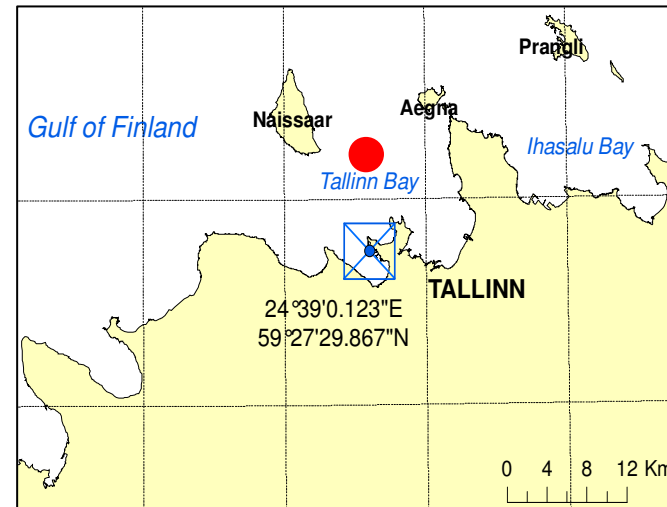
# Motivation

**Demand for extreme water level return periods for coastal planning**  
Coastal civil engineering, harbor engineering, cost efficiency estimations, etc. **Long observation time series are often not available at the point of interest**

**Flood directive 2007/60/EC – flood hazard maps, management plans, etc shall be renewed every six years**



# Study site, goal



**Estimate the return periods of extremely high sea level in the Tallinn Bay**

**To construct a more reliable projection of extreme water levels using ensemble approach**

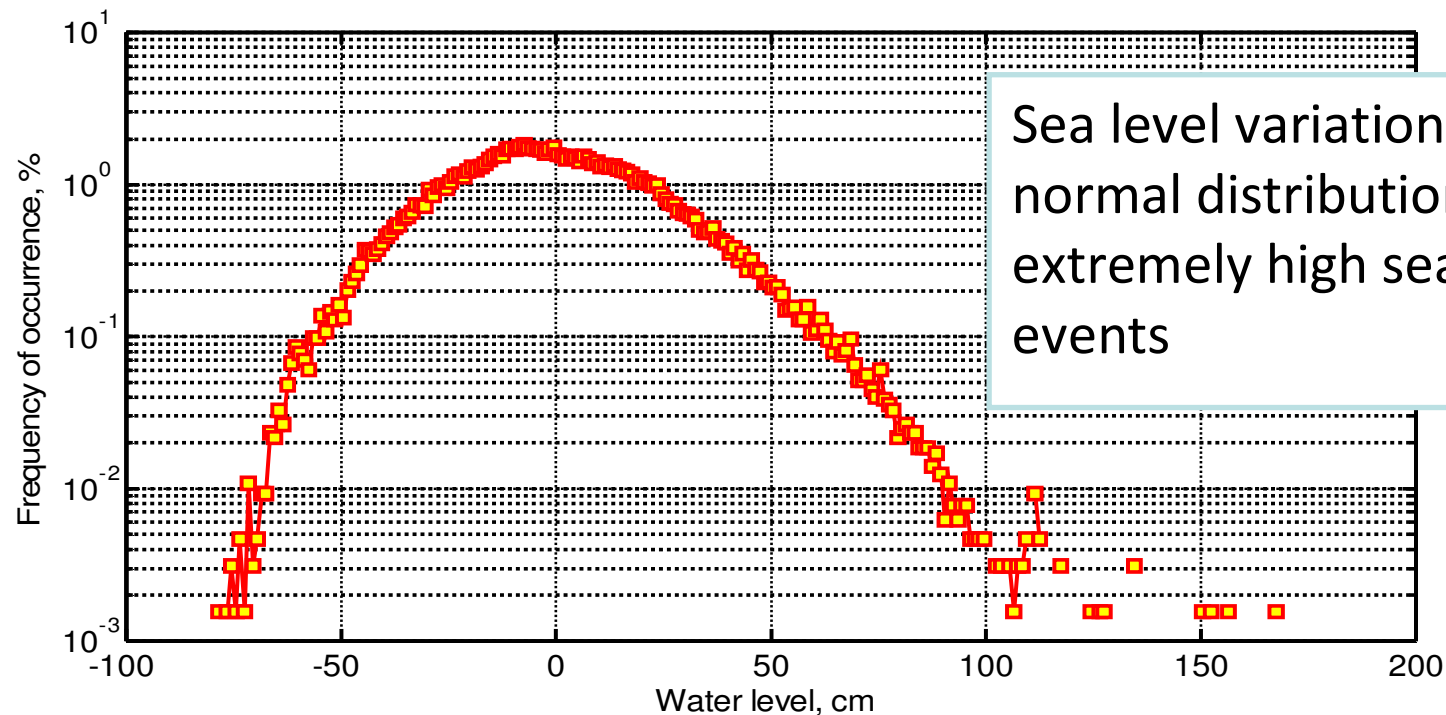
# Available data



Monthly maximum coastal sea level observations for 1961 – 2013

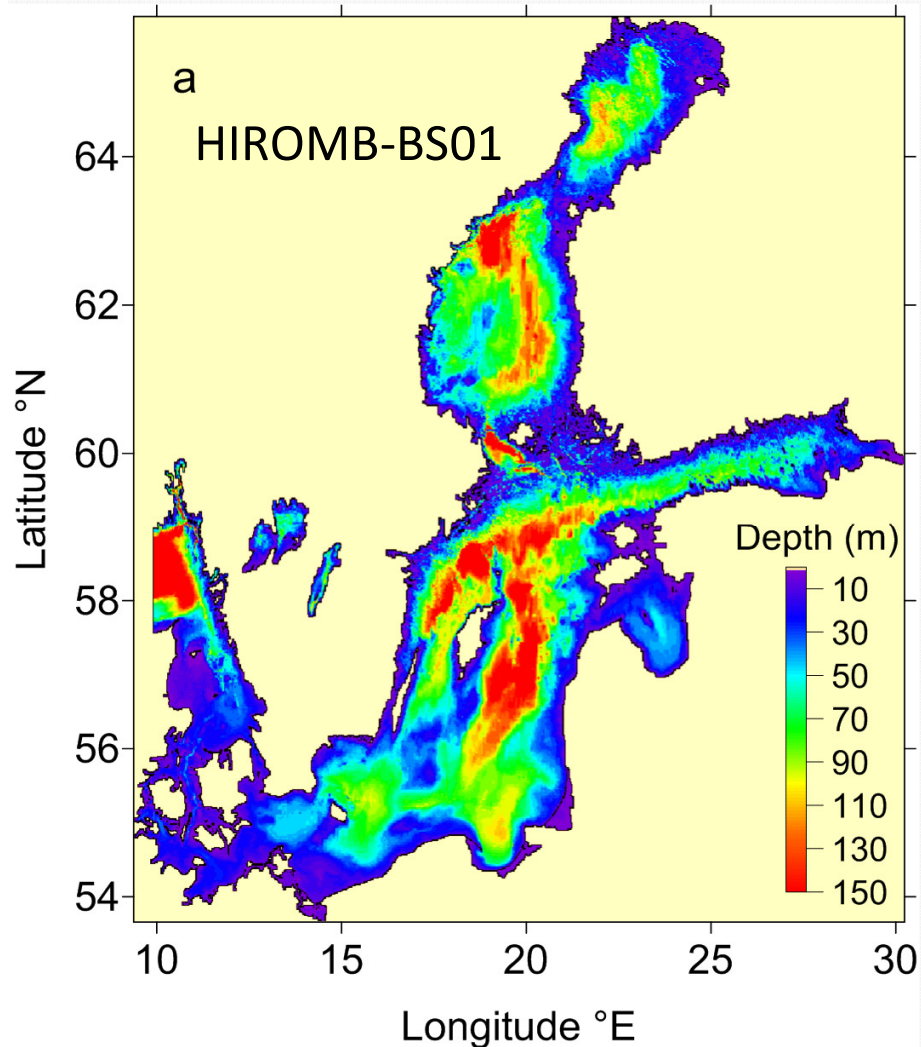
Sea level data from operational model HIROMB for 2006 – 2013

Sea level data from RCO 6h and 1h reanalyses for 1961 – 2005



Sea level variations close to normal distribution except extremely high sea level events

# Model data



## HIROMB-BS01

1.0 nautical mile grid, temporal resolution 1 hour

Forced by HIRLAM-SMHI 22 km, river data from HBV (hydrological model)

Data assimilation: SST, Ice, in-situ T&S

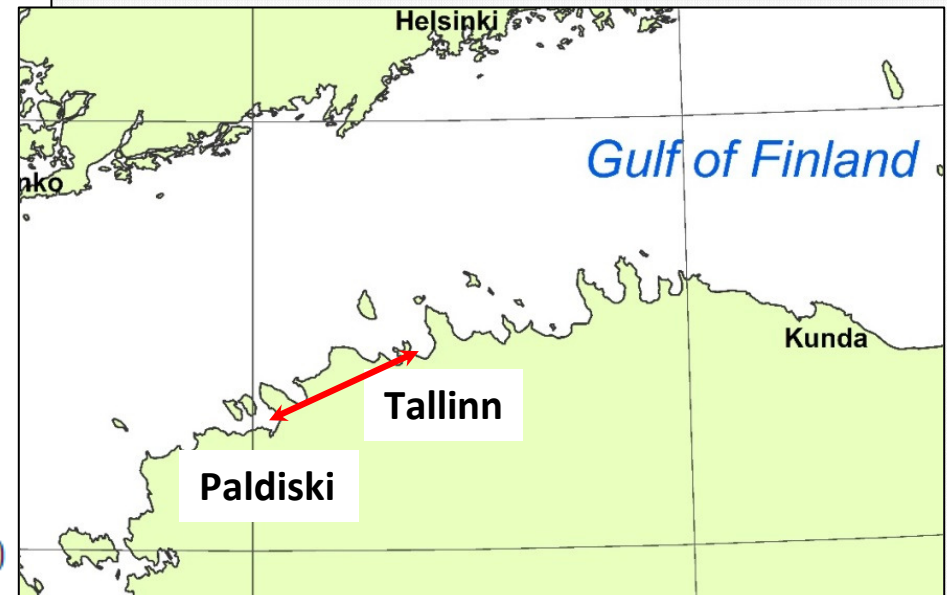
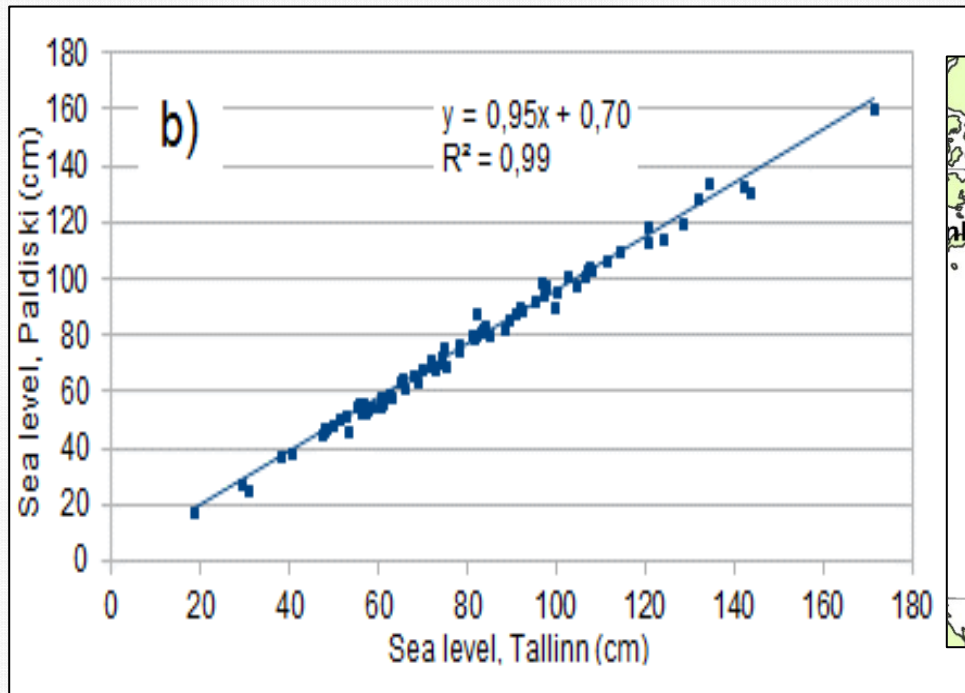
Source of operational sea level forecast

## RCO 6h and RCO 1h

2 nautical mile grid, temporal resolution 6 and 1 hour

Meteorological forcing from a regionalization of the ERA-40 re-analysis

# Combining short term model and long term observation data



The long-term observations are transferred to the study site using linear regression found from short-term model data

High correlation between Tallinn and Paldiski monthly maximum sea level prove the validity of this method

# Extreme value distributions

## Generalized extreme value (GEV)

$$G(y) = \exp\left\{-\left[1 + \xi\left(\frac{y - \mu}{\sigma}\right)\right]^{-1/\xi}\right\}$$

## Gumbel

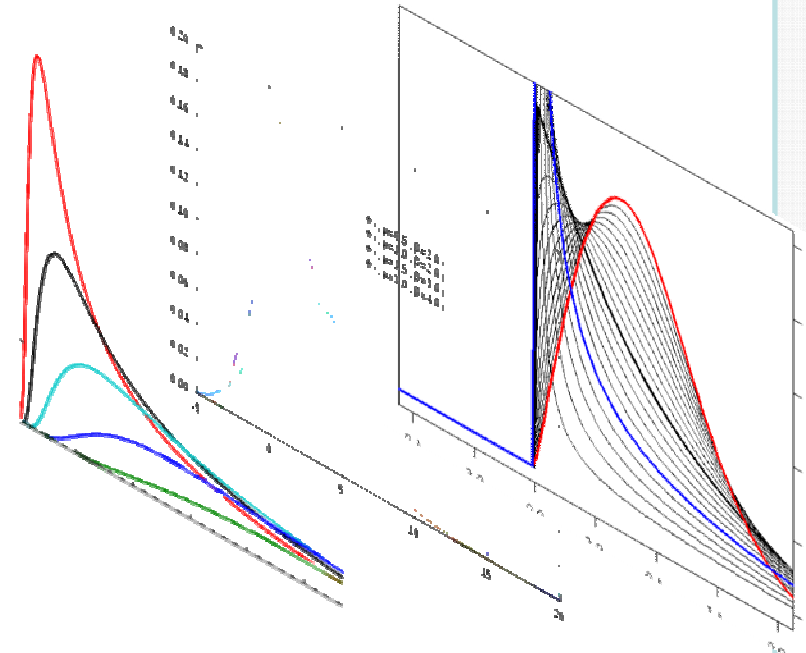
$$\xi \rightarrow 0 \quad \Lambda(y) \sim \exp\{-\exp(-y)\}$$

## Weibull

$$\xi < 0$$

Fréchet, Generalized Pareto (GPA), LogNormal LN3, etc

Different parameterization methods (least squares, best estimate)



# Constructing independent time series

**Extreme value distributions assume independent dataset**

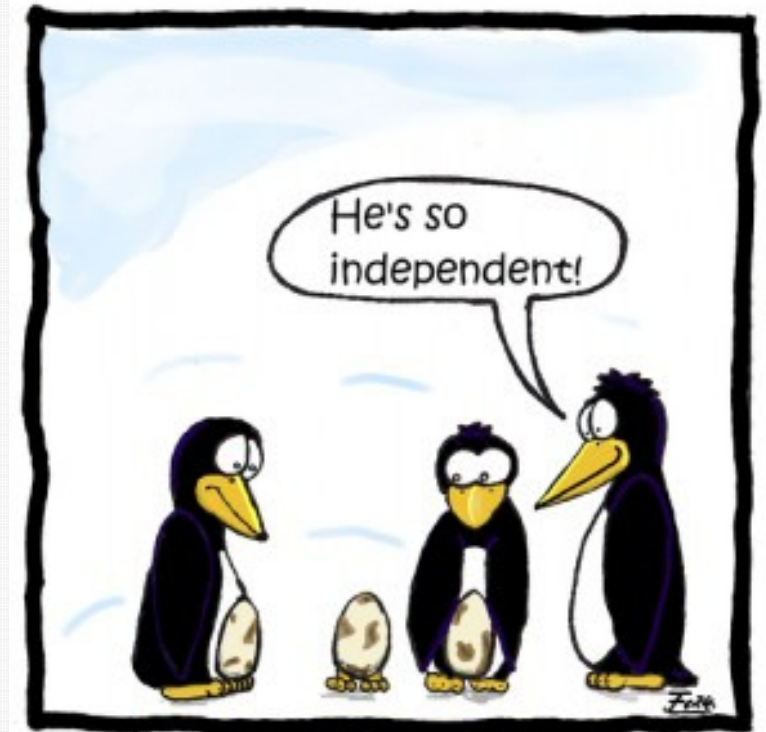
**High resolution sea level data is not independent (influenced by same background components)**

**Possible independent datasets:**

Annual sea level maximums

Storm season sea level maximums

Storm by storm sea level maximums



# Summary 1



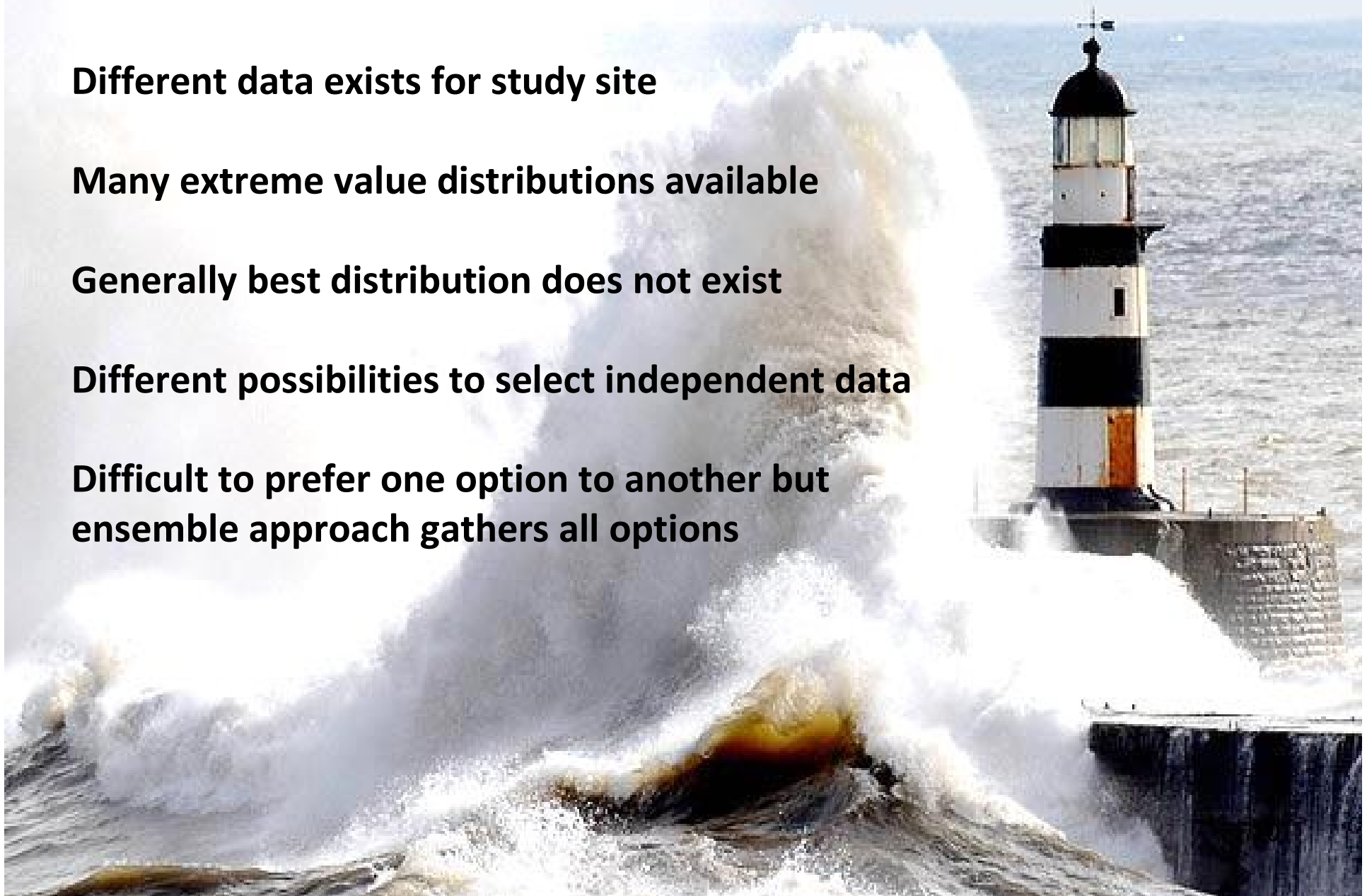
**Different data exists for study site**

**Many extreme value distributions available**

**Generally best distribution does not exist**

**Different possibilities to select independent data**

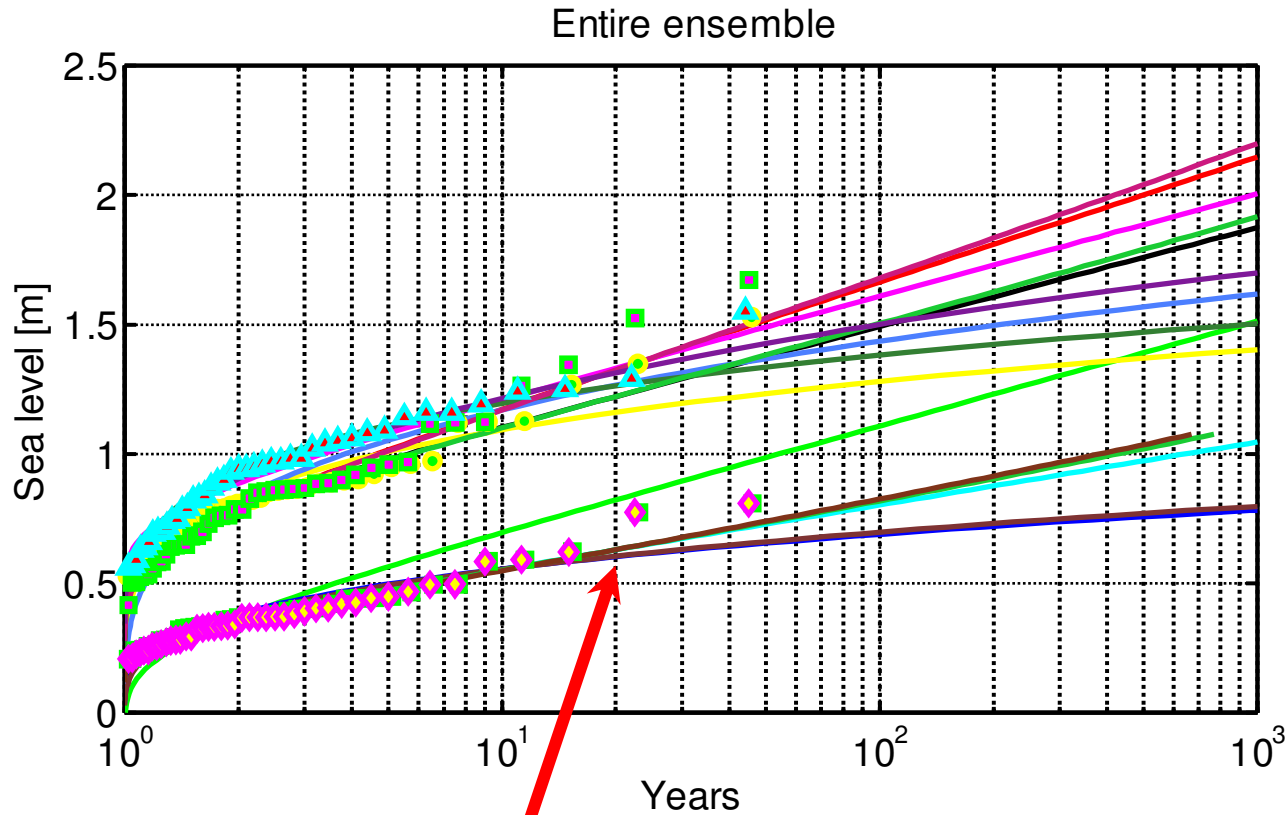
**Difficult to prefer one option to another but ensemble approach gathers all options**



# How to choose an ensemble members?



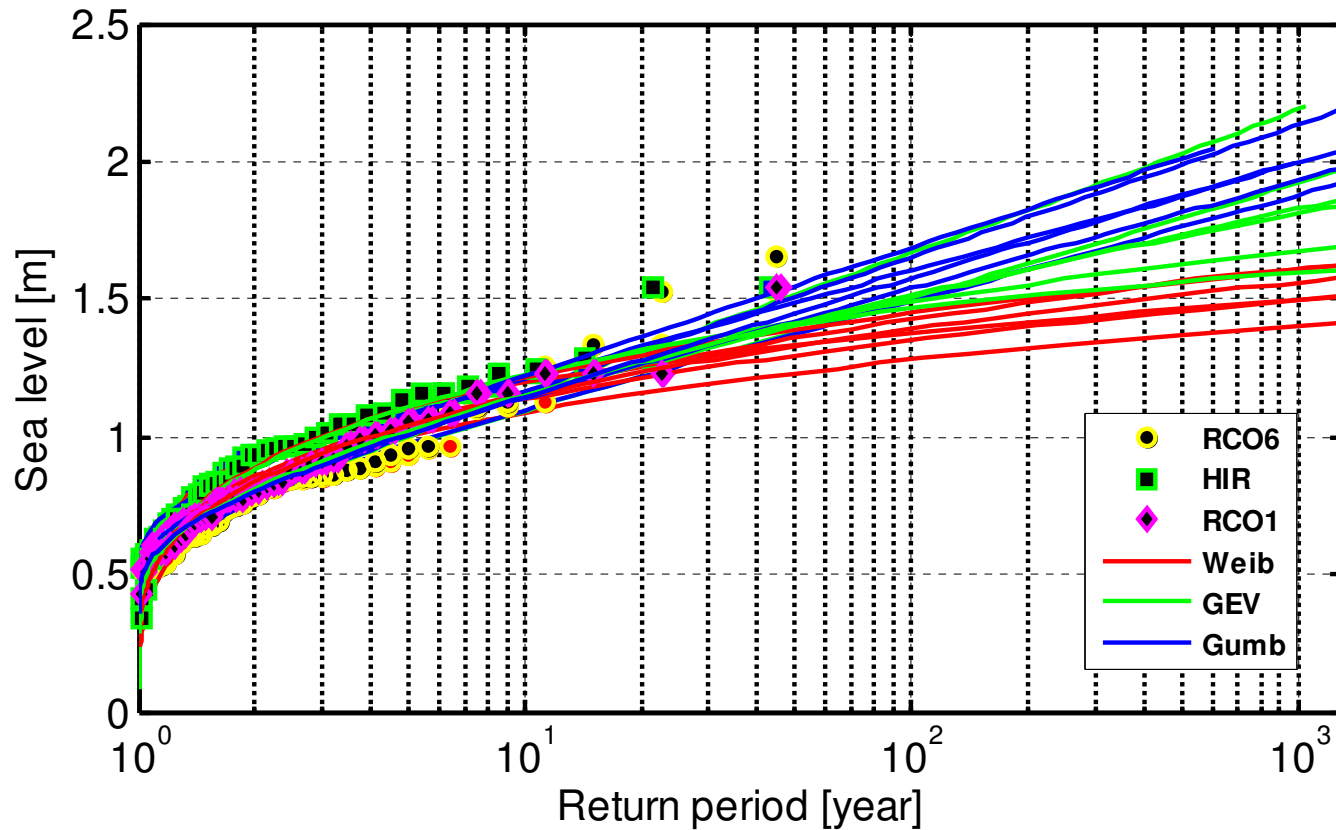
# Choosing ensemble members



Obviously  
unreliable members  
removed

Some members may  
not suit into  
ensemble

# Results



**Weibull distribution „does not predict“ outliers**

**Gumbel distribution gives high sea level extremes**

**GEV distribution predicts intermediate extremes**

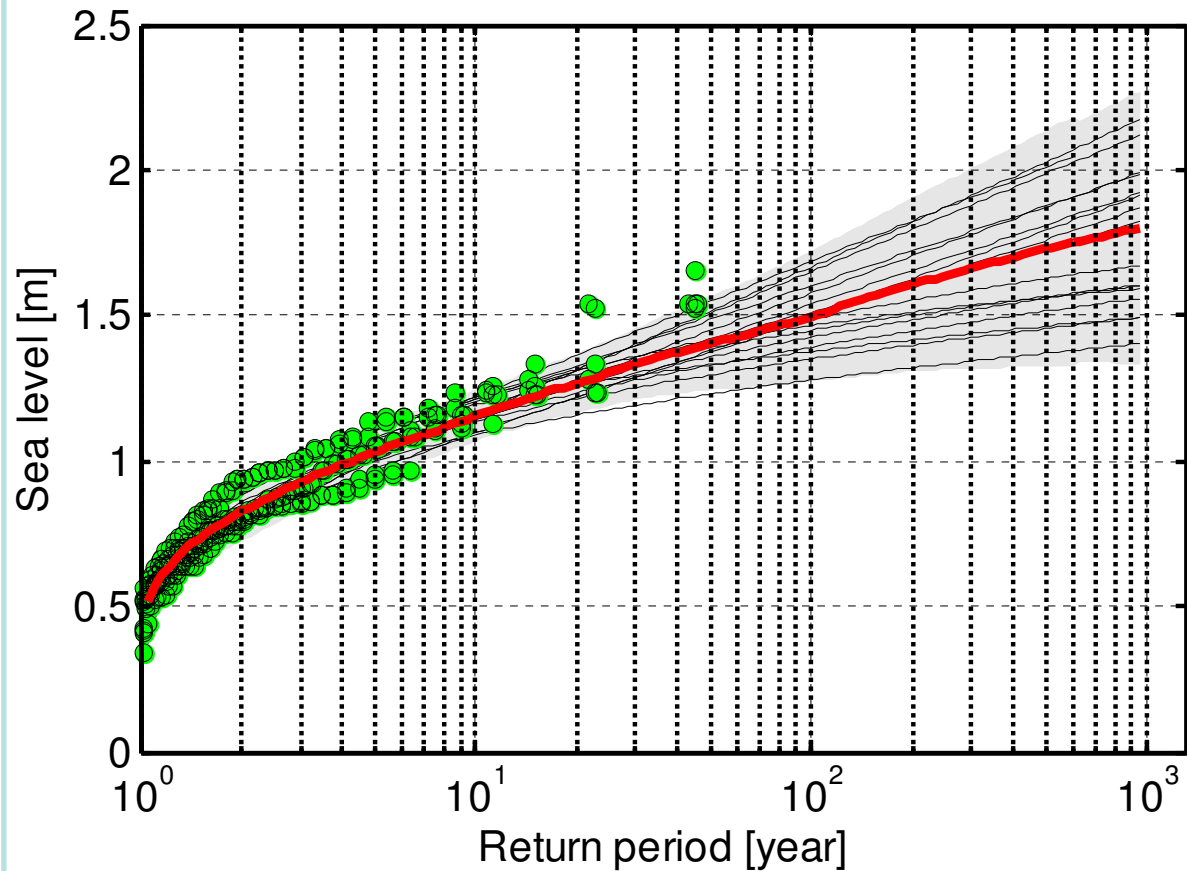
# Results



**Ensemble spread:**  
**25cm for 20 yr**  
**45 cm for 100 yr**  
**80 cm for 500 yr**

**No prediction fits the ensemble average**

**Reasonable match of the ensemble average for 1 in 100 yr event**



# Summary

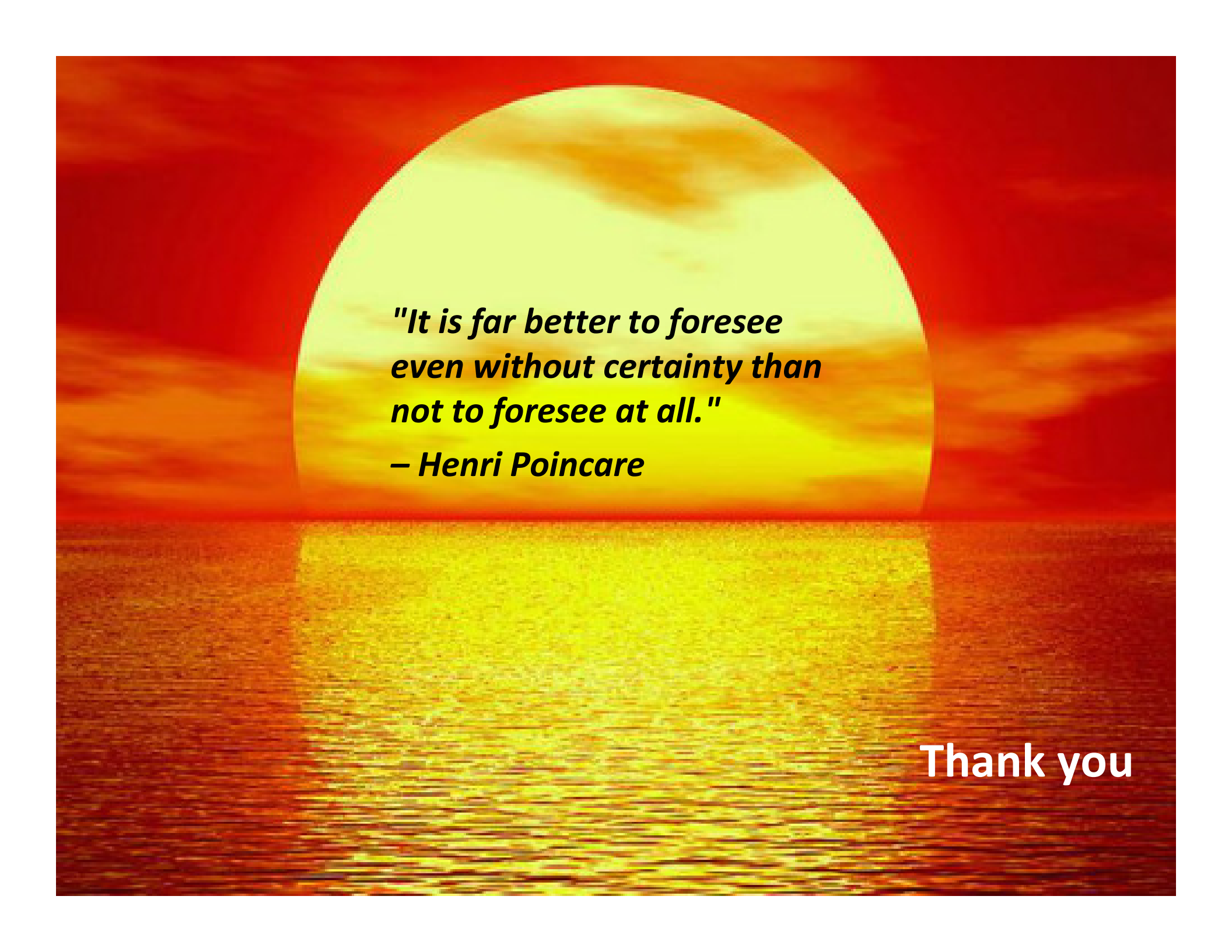


**Choosing single data and method set can be very tricky when estimating sea level extremes**

**The spreading of the entire ensemble is 25 cm for 20 yr, 45 cm for 100 yr and 80 cm for 500 yr return period**

**Reasonable match of the ensemble average for 1 in 100 yr event with the highest measured or hindcast water levels**

**Ensemble approach increases the number of options but gives more informative overview of the situation**



***"It is far better to foresee  
even without certainty than  
not to foresee at all."***

***– Henri Poincare***

**Thank you**