An Analysis of the Diversity in Scenario-based Tsunami Forecasts in the Indian Ocean

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Australian Government
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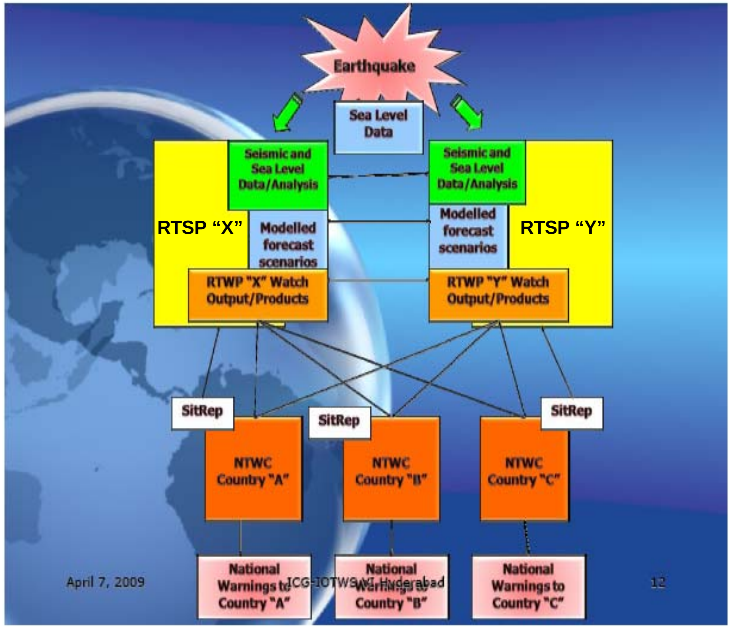
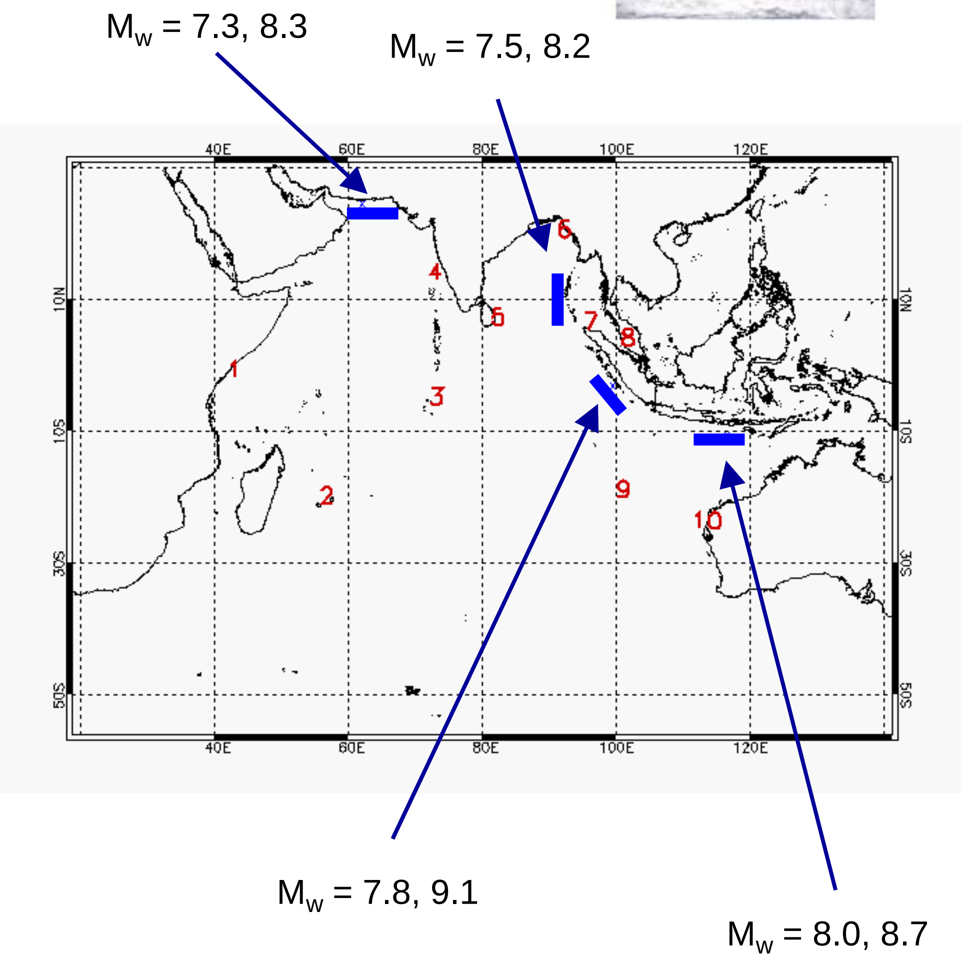
Motivation

- Development of Indian Ocean Tsunami Warning and mitigation System (IOTWS) has occurred rapidly since 2004.
- Important component of the IOTWS is the concept of a Regional Tsunami Service Provider (RTSP)
- RTSP provides tsunami forecasts to one or more National Tsunami Warning Centres (NTWC)
  - Only in last few years that tsunami forecasts and warnings have been based on numerical models
- Aim: Determine how variable the tsunami forecasts from the RTSPs might be



Method

- Eight hypothetical events within the Indian Ocean
  - Four earthquake locations
  - Range of magnitudes
- Emulate real-time conditions (~10 minutes after earthquake)
- Provide epicentre location (lat/lon) and magnitude
  - DON'T provide: hypocentral depth, rupture details (length, width, slip etc.), rupture direction, focal mechanism
- 10 output locations
  - Mostly near coasts (~100m depth)
  - One deep water (Location 9)
- Time series from each participating centre, for each of the 8 hypothetical events at each of the 10 locations

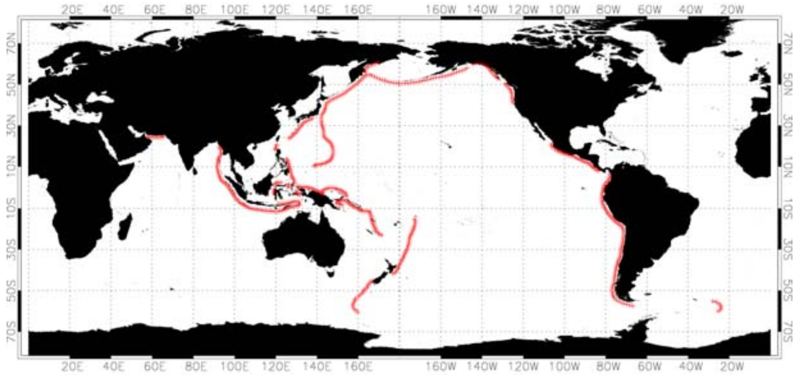


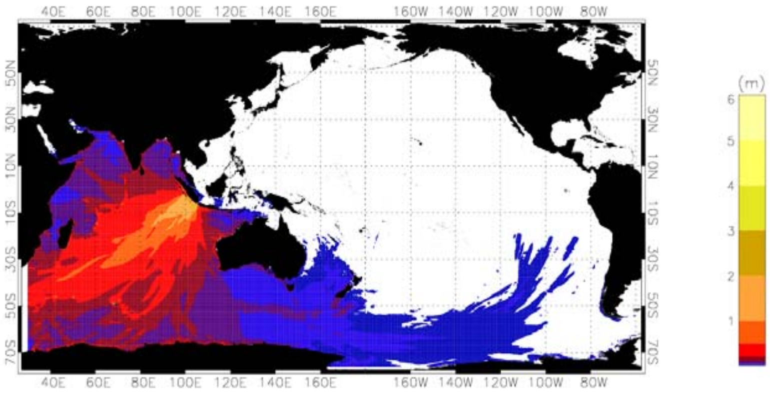
Summary of Conclusions

- Main characteristics of tsunami forecasts are similar
  - Arrival times, characteristics of leading waves
- Also a number of differences
  - Maximum amplitudes (h_{max}), frequency content
- Standard deviation of h_{max} ~ 62% of mean
  - At least some of the diversity is due to length of time series
- Suggests that it is possible that tsunami bulletins from RTSPs may conflict with each other

Operational tsunami forecast and warning

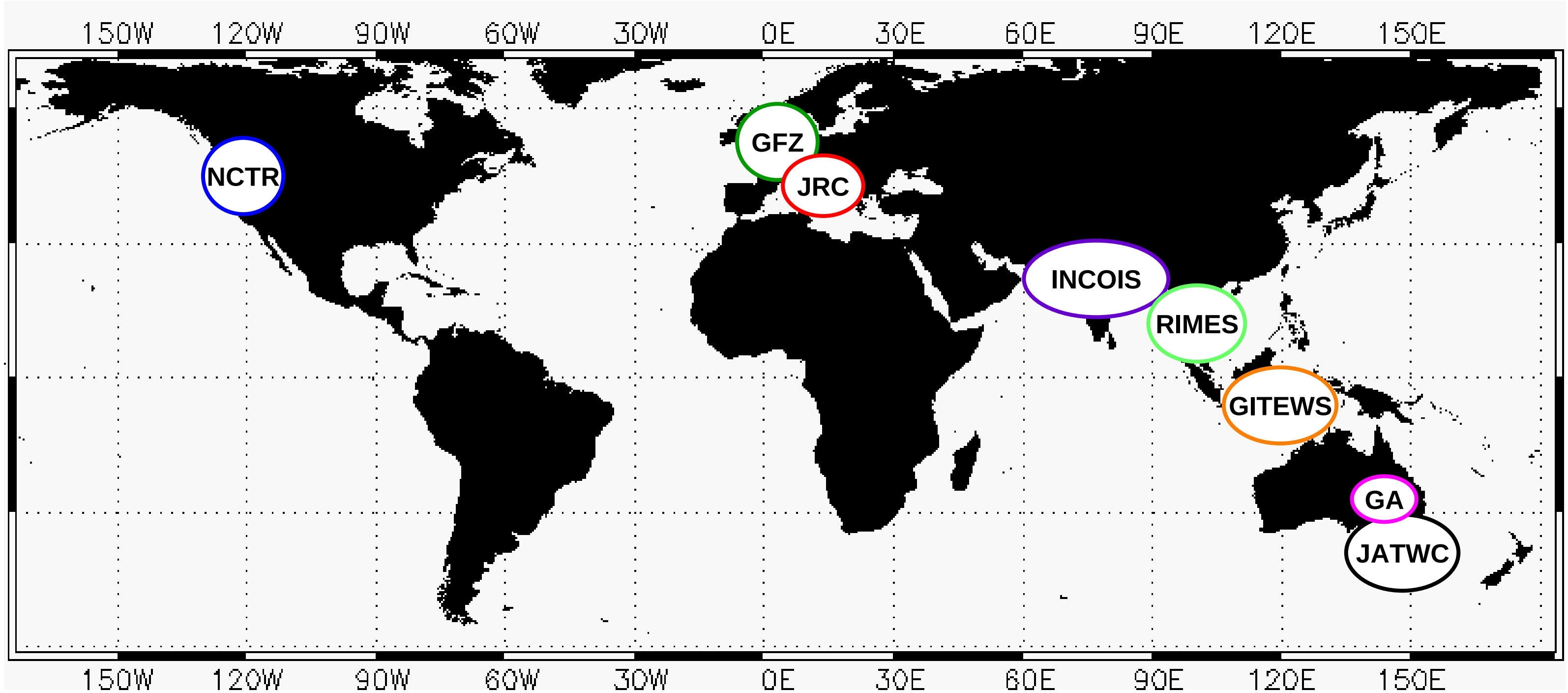
- Can’t predict earthquakes, so don’t know when tsunami will occur
- In most cases, tsunami propagates too fast for event to be dynamically modelled in time to provide warning
- We know where tsunamis are likely to be generated
- Operational tsunami forecast systems based on pre-computed “tsunami scenarios”
- All possible tsunami events have been modelled and archived to produce a “scenario database”
- When an earthquake occurs, can extract closest scenario



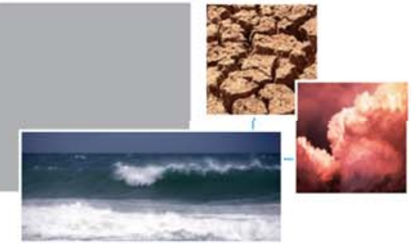


Participating Centres

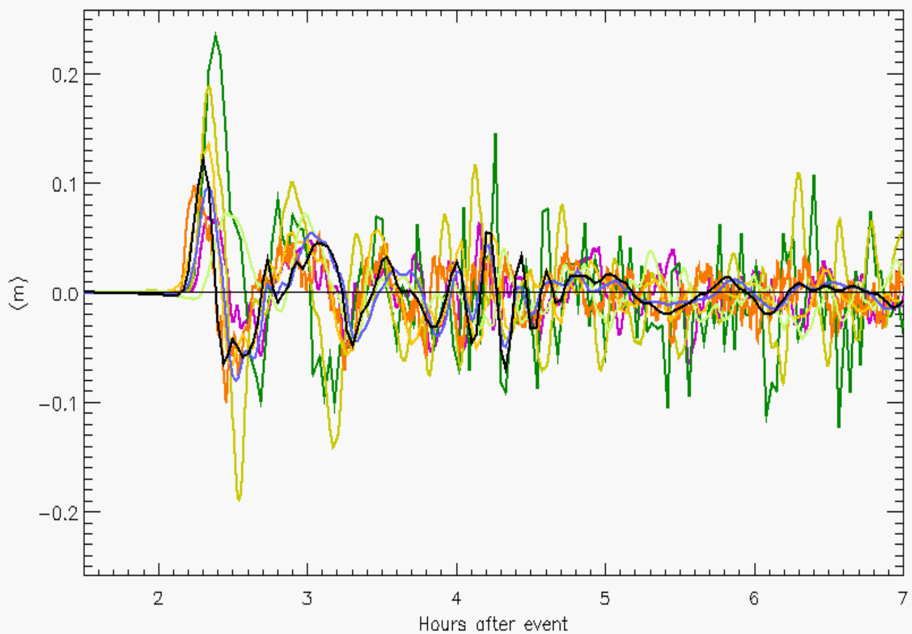
- 8 participating centres
- All have ability to provide tsunami forecasts for Indian Ocean region
  - Most are scenario databases
- Not all existing or proposed RTSPs



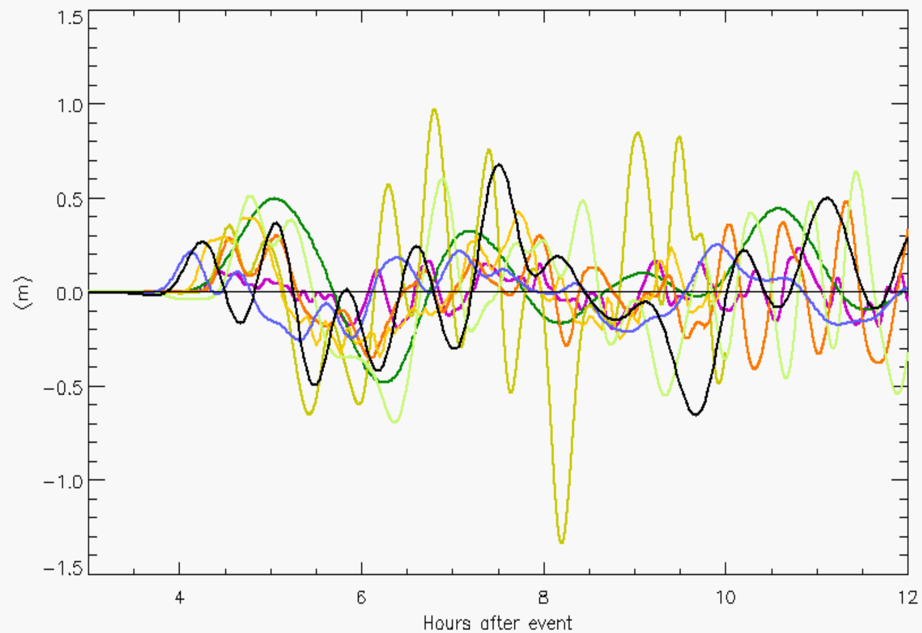
Results

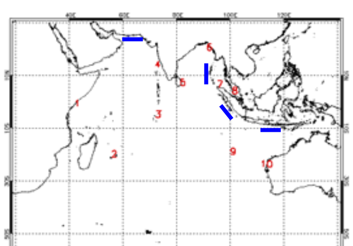


Sunda South B (M_w = 8.7)
Location 9 (Deep water)



Sunda Central B (M_w = 9.1)
Location 10 (Australia)

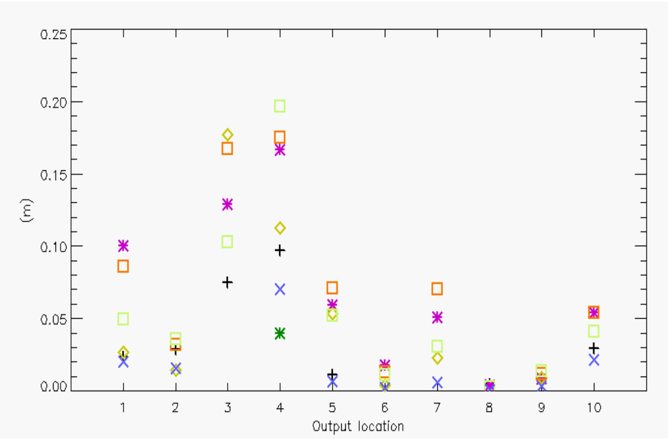




Results

- Consider h_{max} over entire time series
  - RTSP 'exchange' parameter
  - Threat assessments based on h_{max}
- Wide variation in h_{max}
- Suggest tsunami bulletins may conflict

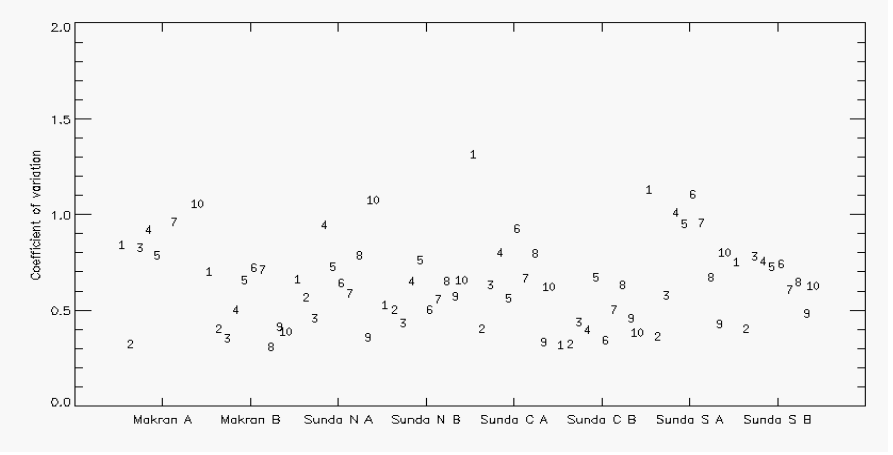
Makran B; M_w = 8.3

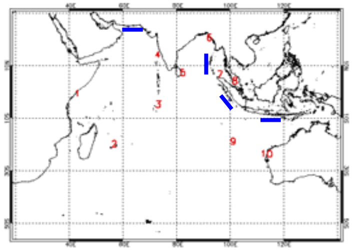


- Coefficient of variation (CoV) as an assessment of how diverse a forecast is:

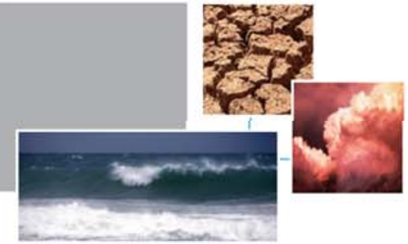
$$c_v = \frac{\sigma}{\mu}$$

- Average CoV ~ 0.62



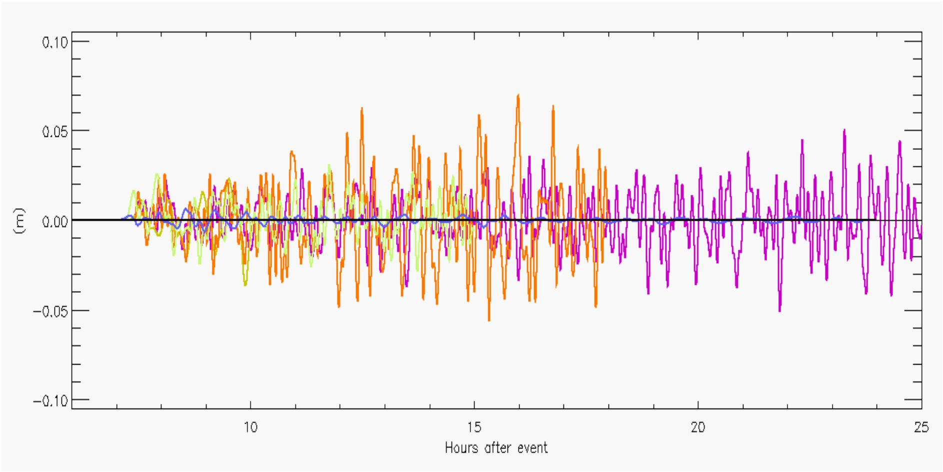


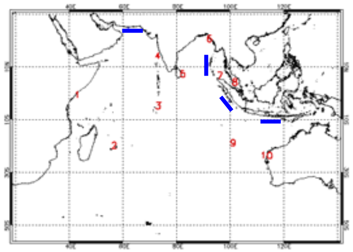
Results



- Some factors that are likely to cause the variability are:
  - Initial conditions
    - Rupture definition (length, width etc.)
    - Rupture generation
  - Model physics and numerics
  - Bathymetry/output location
- Length of time series
  - 10 hours – 30 hours

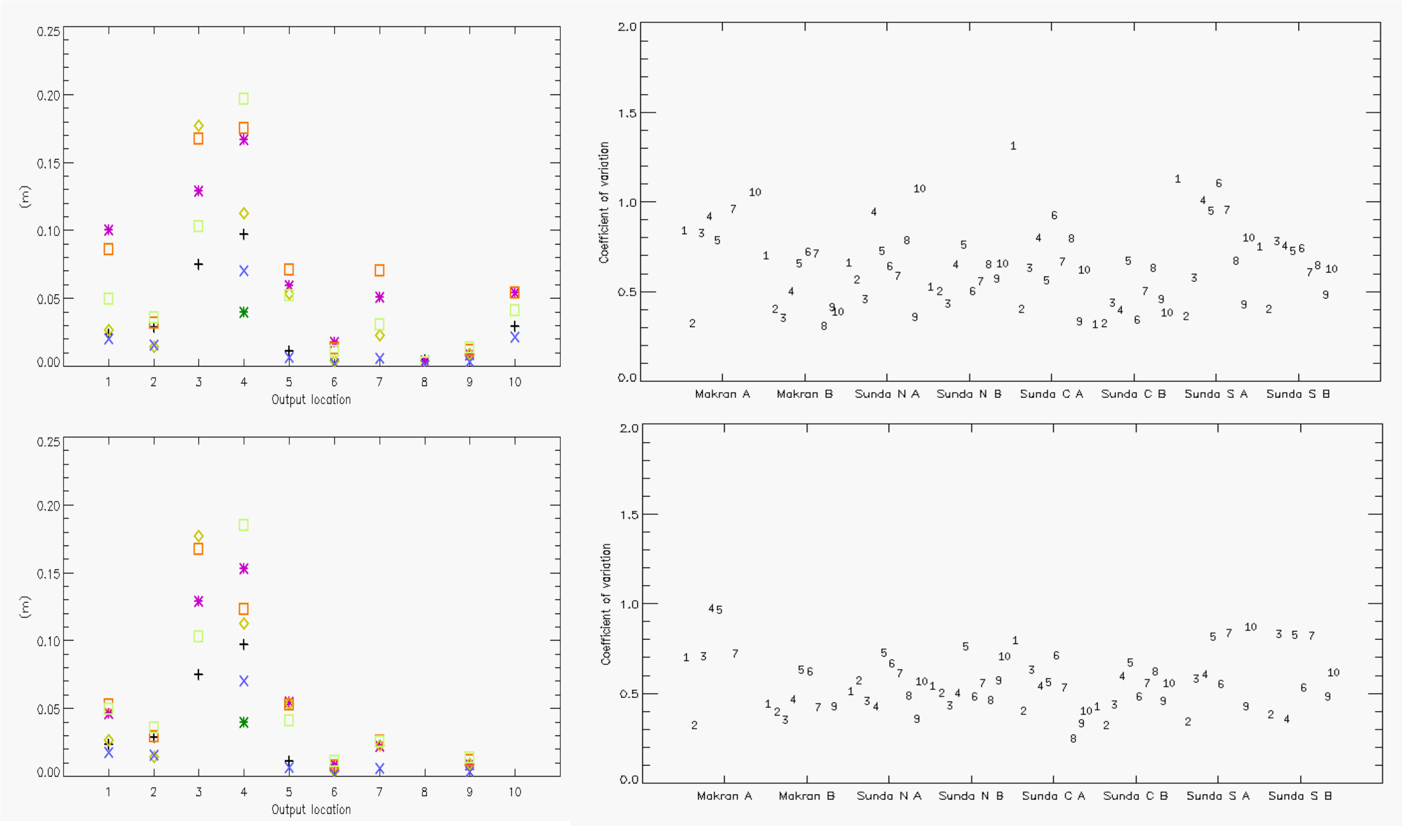
Makran A (M_w = 7.3)
Location 6 (Bangaldesh)





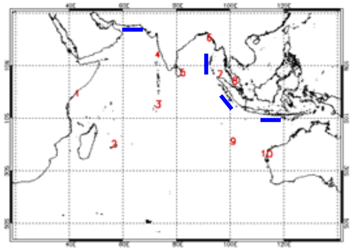
Results

Makran B; M_w = 8.3

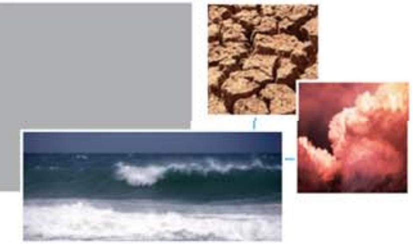


- Full time series
  - CoV = ~0.62

- First 10 hours
  - CoV = ~0.54



Summary and Concluding Remarks



- Tsunami “forecasts” from 8 centres, 8 hypothetical events, 10 output locations
- Main characteristics are similar
  - Arrival times, characteristics of leading waves
- Also a number of differences
  - Maximum amplitudes (h_{max}), frequency content
- Standard deviation of h_{max} ~62% of mean
- Suggests that it is possible that tsunami bulletins from RTSPs may conflict with each other
  - Not necessarily a bad thing
  - Represents range of uncertainty that exists in real-time situation
  - NTWCs receiving multiple forecasts need to formulate an appropriate warning strategy
- At least some of the diversity is due to length of time series
  - Recommend to ICG/IOTWS that h_{max} provided from time series of same length to optimise “interoperability”

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Thank you

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Output locations

Loc	Lon.	Lat.	BOM	GA	RIMES	JRC	GFZ	GITEWS	INCOIS	NCTR	mean	st dev
1	41.40	-1.90	138.0	75.0	n/a	n/a	61.0	12.1	85.8	185.9	93.0	61.0
2	55.73	-21.00	310.5	69.0	n/a	n/a	323.0	498.7	656.9	2141.8	666.6	749.2
3	72.10	-6.00	47.0	53.0	n/a	4.0	57.0	27.5	59.0	n/a	41.2	21.5
4	74.40	13.30	49.0	50.0	n/a	34.0	45.0	39.4	48.8	41.6	44.0	5.9
5	81.33	6.16	452.0	32.0	53.0	n/a	19.0	19.8	54.9	652.6	183.3	259.0
6	91.20	20.50	69.0	68.0	n/a	83.0	83.0	163.2	84.9	125.0	96.6	34.9
7	95.10	5.50	96.0	39.0	n/a	581.0	35.0	41.2	58.3	204.0	150.7	198.9
8	100.70	3.00	80.0	74.0	n/a	66.0	23.0	52.1	19.8	39.2	50.6	24.1
9	100.00	-20.00	5,786.0	5786.0	n/a	6000.0	5784.0	5,958.0	5998.9	6094.8	5,915.4	128.4
10	113.30	-24.80	27.0	29.0	n/a	4.0	8.0	25.0	7.0	3.8	14.8	11.5

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