Storm Surge Climatology:
JCOMM Scientific and Technical Symposium on Storm Surges

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CLIMAR-III Gdynia Poland May 6-9, 2008
OUTLINE

• What is a storm surge?
• JCOMM ETWS initiatives
• Storm Surge Symposium – Climate Session: key results and recommendations
• GLOSS and PSMSL
• Proposed actions and links to broader marine climate initiatives

GIWW on the morning that Katrina made landfall.
<table>
<thead>
<tr>
<th>YEAR</th>
<th>COUNTRIES</th>
<th>DEATHS</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1960</td>
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<tr>
<td>1972</td>
<td>India</td>
<td>5,000</td>
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May 3, 2008
Myanmar
22,500+
Storm Surge

Oscillations of the water level in a coastal or inland water body in the period range of a few minutes to a few days as a result of forcing from atmospheric weather systems.

“Storm tide” is the combined water level associated with the simultaneous effects of the astronomical tide, storm surge and breaking wave set-up.

Surge can be measured directly at coastal tidal stations as the difference between the forecasted tide and the observed rise of water.

- Tropical or extratropical cyclones
- Remote or meso-scale forcing
- Continental shelf waves, edge waves and topographically forced Rossby waves
Water Level Components of a Storm Tide

- Intermittent Wave Runup
- Ocean Waves
- Extreme Winds
- Currents
- Inundation
- Storm Tide
- Wave Setup
- Surge
- Expected High Tide
- MSL
- LAT
- HAT
- SWL

Surges may be negative or positive

Positive surges cause most of the destruction and loss of life on land

Negative surge impacts are mostly economic, e.g. in harbour approaches
<table>
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<tr>
<th>Stations</th>
<th>Param</th>
<th>Period</th>
<th>Instr</th>
<th>Dig/Analog</th>
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<tr>
<td>21</td>
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<td>D</td>
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<td>Web based</td>
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<td>D</td>
<td>location, datum vs ground</td>
<td>maxima</td>
<td>Japan</td>
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<td>1</td>
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<td>ADCP</td>
<td>D</td>
<td>document</td>
<td>-</td>
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## JCOMM ETWS: Hindcasted databases on storm surges (12)

<table>
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<th>Source</th>
<th>Model</th>
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<th>Country</th>
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<td>1958-2002</td>
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<tr>
<td></td>
<td>Nivmar</td>
<td>1998-present</td>
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<td>web.dmi.dk/pub/STOWASUS-2100/</td>
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<tr>
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<td>non oper.</td>
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<td>2005-present</td>
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<td>1962 - 1999</td>
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<td>Operational</td>
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<td>Operational</td>
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<tr>
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<td>-</td>
<td>United Kingdom</td>
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</table>
Symposium on Storm Surges - Session 8

Storm Surge Climate and Climate Change

• 8.1 Extreme Sea Levels, Coastal Flooding and Climate Change; Keith Thompson, Dalhousie University
• 8.2 Assessing the impact of climate change on storm surges in southern Australia; Kathleen McInnes, CSIRO
• 8.3 Impact on the global warming on the intensity of future tropical storm; Jai-Ho Oh, Pukyong National University
• 8.4 Spatially high resolved projections of possible future changes in North Sea storm surge extremes; Katja Woth, GKSS Research Center
• 8.5 Exploring the feasibility of regional typhoon modelling; Frauke Feser, GKSS Research Center
• 8.6 Statistics of abnormal sea states around Korean Peninsula; Jong Chan Lee, KORDI
• 8.7 Storm Surges in Tideless Seas - Southern Baltic Sea; Marzenna Sztobryn, Institute of Meteorology and Water Management

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• 9.1 Developments in storm tide modelling and risk assessment in the Australian region; Bruce Harper, Systems Engineering Australia Pty Ltd.
• 9.2 A surge response surface approach to the estimation of surge hazards in the vicinity of New Orleans; Donald Resio, US Army Corps of Engineers
Classical Analysis of Extremes

Halifax Annual Maxima and Minima, 1920–2001

Return Level plot: Return level against return period, assuming Type I
Can We Recover The Distribution of Extremes Using the Barotropic Model?

**Model:** Outer surge model, run from 1960 to 1999

**Winds:** AES40, 6h, 1958-2000, 0.63º (lat) and 0.83º (lon)

**Air pressure:** Estimated from winds to within 3mb

**Output:** Hourly hindcasts stored for each grid point

**Analysis:** Gumbel distribution fit to annual maxima

*For details see:*

40 Year Return Levels for Storm Surges

![Graphs and map showing observed and predicted storm surge levels]

**Observed**

**Predicted**

**Station Number**

- Tide Gauge

![Station codes and locations on the map]
40 Year Return Level for Storm Surges

Return Level (m)
Storm surge return periods:

Hydrodynamic modelling and extreme value statistical analysis to evaluate storm surge return levels from observed set of events

- Three tide gauge records used for event selection
- Tidal signal removed using low pass filter
- Threshold approach used to select events (489 events identified from 38 years of data)
Storm surge at Masan during typhoon Maemi (Black : 1 minute raw SSH, Red : 1 minute filtered SSH, Blue : 1 hour SSH)

Maximum surge Heights Based on 1 year HM:
162 cm (1 hr), 226 cm (Raw), 211 cm (filtered)
NUMBER OF STORM SURGES AND DAYS WITH SEA ICE

- Normalized number of events
- Seasonal number of storm surges
- Number of days with sea ice

Years:
- 1950/51
- 1953/54
- 1956/57
- 1959/60
- 1962/63
- 1965/66
- 1968/69
- 1971/72
- 1974/75
- 1977/78
- 1980/81
- 1983/84
- 1986/87
- 1989/90
- 1992/93
- 1995/96
- 1998/99
- 2001/02
- 2004/05
INUNDATION MAPS

1. by probability of occurrence
   10%
   1% and
   0.5% (hot spot),

2. Hypothetical storm by forecast model
   input data consisted of values from the most unfavorable boundary conditions known to have occurred in area

3. Max SL even observed + linear trend

COUPLED HYDROLOGICAL MODELS: HEC-RAS (HD);
MIKE11(HD,P)
# JCOMM Symposium on Storm Surges

## Agreed Recommendations and Actions

<table>
<thead>
<tr>
<th><strong>Observations and Data</strong></th>
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<tbody>
<tr>
<td>National access to, or development of, high resolution, near shore, bathymetric data and coastal zone topographic data sets highly desirable</td>
<td>National agencies</td>
</tr>
<tr>
<td><strong>Enhanced GLOSS network to support storm surge risk assessments, research and forecasting, with recommended 1 minute sampling</strong></td>
<td>JCOMM/GLOSS GE</td>
</tr>
<tr>
<td><strong>Enhance in situ networks for all relevant variables, including higher time resolution</strong></td>
<td>National agencies</td>
</tr>
<tr>
<td>Look to utilize other observation platforms to enhance in situ data; e.g. tsunameters</td>
<td>National agencies, JCOMM and Secretariat</td>
</tr>
<tr>
<td>Countries should prioritize data acquisition on the basis of risk analysis, including vulnerability and hazard impact probability</td>
<td>National agencies</td>
</tr>
<tr>
<td><strong>Global access to existing storm surge data sets, perhaps through a storm surge metadata catalogue; Development of interoperable storm surge databases and climatologies</strong></td>
<td>JCOMM/ETWS, Secretariat</td>
</tr>
</tbody>
</table>
## Future Research and Development

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved physics and physical processes in the models; e.g. wave/current and wind/current interactions</td>
<td>SS research community</td>
</tr>
<tr>
<td>Need development of fully coupled basin / coastal / tide / wave / atmosphere models and programme for continuous improvement</td>
<td></td>
</tr>
<tr>
<td>Improvements required in total water level predictions as a result of tide, wave and surge interactions</td>
<td></td>
</tr>
<tr>
<td>Coupled hydrologic, hydraulic and surge models for inundation</td>
<td></td>
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<tr>
<td>Research required on mesoscale wind forced events and remotely forced inundation events</td>
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</tr>
<tr>
<td>Develop methodologies to project changes in storm surge climate over the next century, with associated measures of uncertainty</td>
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<tr>
<td>Further development of empirical techniques, e.g. AI, neural networks, statistical</td>
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<tr>
<td>Investigate improved means to incorporate uncertainty into forecast guidance</td>
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<tr>
<td>Pursue studies of model sensitivity to spatial and temporal resolution for</td>
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</tbody>
</table>
Global Sea Level Observing System

- GLOSS aims at the establishment of high quality global and regional sea level networks for application to climate, oceanographic and coastal sea level research.
- The main component of GLOSS is the 'Global Core Network' (GCN) of 290 sea level stations around the world for long term climate change and oceanographic sea level monitoring.
Access to Sea Level Data

- **PSMSL** is the global data bank for long term sea level change information from tide gauges. **Monthly and annual** mean values are available online at [www.pol.ac.uk/psmsl/](http://www.pol.ac.uk/psmsl/)

- **High frequency** sea level data (typically hourly values) is more complicated to obtain than MSL data due to perception of either military or commercial value (unlike MSL). This situation has improved in recent years.

- There is still no single global data centre for HF data, but considerable data is available from British Oceanographic Data Centre (BODC), and University of Hawaii Sea Level Center (UHSLC) which has its Research Quality Data Set (RQDS) which is, to a great extent, a GLOSS DM HF data set.

- Steps are now being taken to merge these 2 DM HF data sets as far as possible for the benefit of users.

- Aside from GLOSS, a user wanting HF data from a particular region must consult one of a number of national and international (regional) data centres, in different formats and possibly subject to a charge.
What Next?

• Develop a global storm surge data base,
  – for calibrating numerical models, background data to infer the influence of climate change on storm surges generated by tropical and extra-tropical cyclones. – de-tide GLOSS HF 1-hour record

• Develop new storm surge models for meso-scale and remote forcing.

• Upgrade storm surge models to include effects of continental shelf waves, edge waves and topographically forced Rossby waves.

• Encourage additional storm surge hindcast climatologies

• Document storm surge data bases (sea level) and hindcasts in JCOMM catalogues

• Develop possible indices and link with ETCCDI

• Establish stronger links with GLOSS
Thank you.
Storm Surges vs. Tsunamis

**Similarities**
Long gravity waves.
Both causes coastal inundation.

**Differences**
Storm surges can occur only in shallow water.
Storm surges interact with tides, more than tsunamis
Different forcing.
Program - JCOMM Scientific and Technical Symposium on Storm Surges
2 - 6 October 2007, Seoul, Korea Rep

• 0.2 Storm Surge Manual
• 0.1 Introduction of JCOMM activities
• 0 Introduction
• 1 Storm Surge Modelling
• 2 Operational Storm Surge Forecasting
• 3 MetOcean Forcing
• 4 MetOcean Forcing Observations
• 5 Regional Studies
• 6 Regional Application
• 7 Case Studies
• 8 Storm Surge Climate and Climate Change
• 9 Risk and Impacts
• 10 Poster Session

Symposium Web site at surgesymposium.org
PSMSL sites
Category 1: "Operational" stations for which the latest data is 2003 or later
Category 2: "Probably operational" stations for which the latest data is within the period 1993-2002.
Category 3: "Historical" stations for which the latest data is earlier than 1993.
Category 4: "Stations for which no PSMSL data exist."