Assessing climate risks for seaports: Scoping workshop
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Ports: Range of physical settings and environmental controls

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Synopsis

Seaports: major physical settings

Key environmental factor changes impacting seaports

Distribution of seaports in Europe according to physical setting

Overview of challenges for the different types/groups of seaports

Conclusions and some thoughts on the way forward
Seaports: Major physical settings

A major differentiation can be made according to seaport location relative to the open sea

• Open seaports (direct access to the open sea)
• Low estuarine ports (sea access by short navigation through a tidal river-estuary)
• Upper estuarine ports (access to the sea by long navigation through a tidal river-estuary)

Each of the above types of seaports is associated with different challenges due to (amongst others):

• Vessel, land infrastructure and market innovations/developments
• Changes in environmental controls due to climate change
Key environmental factor changes impacting seaports

Ports are going to be greatly affected by climate change (CC)

Major CC factors will affect open seaports and estuarine ports:

- Mean sea level rise
- Storm waves/surges and winds
- Changes in precipitation means and extremes
- Changes in temperature mean and extremes
Distribution of seaports in Europe according to physical setting

Distribution of European ports

Different challenges for the different seaport types

- Open sea ports
- Estuarine Ports (low and upper)
Open sea ports

Found mostly in micro and meso-tidal environments, i.e. in Europe in the Mediterranean, Black and Baltic Seas

Their physical setting is controlled mostly by wind-induced waves

Changes in mean SLR, storm surge intensity/frequency, and changes in the direction of wind and waves will have major impacts on e.g.
- inundation of port infrastructure
- the wave force on breakwaters
- propagation of waves into ports and vessel safety (approach and berth)

In addition, note that major hinterland connections (roads/rail) to open sea ports are often also coastal

A preliminary study of the European open sea ports has shown a low and fragmented availability of information that would be required to identify/model the present environmental conditions (hydrodynamics and morphodynamics) and assess future risks and adaptation needs/options
Estuarine ports

Found mostly in meso and macro-tidal environments (i.e. in Europe the Atlantic and North Sea Coast)

Their physical setting is highly dynamic in terms of
- tidal/riverine hydrodynamics (i.e. strong, changing flows and changing water levels),
- sediment dynamics (i.e. movement of large volumes of sediment); and
- morphodynamics (i.e. large and frequent changes in morphology of e.g. approach channels and berths)

Therefore, changes in mean SLR, storm surge intensity/frequency, as well as precipitation changes affecting riverine flow and levels will have major impacts.

A preliminary study of the European estuarine ports has also shown a low/fragmented availability of information that would be required to identify/model the present environmental conditions (hydrodynamics and morphodynamics) and assess future risks and adaptation needs/options.
Conclusions

Ports may be distinguished according to their physical settings into: open sea ports and (low and upper) estuarine ports

These will be affected in different ways by climate change (which is also going to be spatio-temporally variable)

Preliminary analysis shows that, even at the European level, important information required to identify/model the present hydro- and morphodynamic conditions of ports is not readily available for the vast majority of ports – the ‘data paradox’. Projections for the future are, therefore, particularly difficult

Moreover, shipping and ports operate with ‘partners’ at a global level

Therefore, collation and collection of relevant data at a global level is required
The way forward?

Creating a global database of all relevant information needed to identify present hydro- and morphodynamic conditions of ports and allow for future projections for the purposes of assessing risks, vulnerability and adaptation needs/options

The database development would benefit from targeted case-studies that would help identify the necessary information to be collated/collected as well as the analytical tools/methodologies

Targeted case-studies: selection should be guided by differences in physical settings and associated challenges (in addition to other parameters, e.g. economic)

After all we must stay ahead of the weather
Thank you!!
A large Mediterranean seaport with direct access to the open sea
The Catalan coast is under severe erosion (Jimenez et al., 2011) due to increasing wave energy
Low estuarine ports: Southampton, UK

- Bulk cargo
- Containers
- Vehicle transport
- Cruise ships and
- Recreation vessels
- Oil/petrochemical terminal
Low estuarine ports: Southampton, UK

Southampton Water, Southern UK. Diverse uses of the port region and its approaches (CASI false colour image)

Extensive research shows that estuarine morphology and hydrodynamics are sensitive to even small changes in environmental and anthropogenic forcing (e.g. channel deepening)
Upper estuarine ports: Hamburg, Germany

One of the 3 largest European ports (turnover of 132 Mio. tons and > than 9 Mio TEU in 2011)

The estuarine port is accessed through ~100 km navigation along the (tidal) river Elbe
For example, growth in vessel dimensions: container vessels

Vessel dimensions since 1950s (J-P. Rodrigue, 2009 Hofstra University).

Greater needs in approach channel and berth manoeuvrability and depths.
Sea level rise in Europe: Trends and projections


Full range: 75 – 190 cm by 2100
Vermeer & Rahmstorf, PNAS 2009
## Major climate change impacts on ports

<table>
<thead>
<tr>
<th>Factor</th>
<th>Impacts</th>
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<tbody>
<tr>
<td><strong>Sea level (mean and extreme)</strong></td>
<td>Open sea ports, estuarine ports (and inland waterway ports)</td>
</tr>
<tr>
<td>• Mean sea level changes</td>
<td>Damages in port infrastructure/cargo from incremental and/or catastrophic inundation and wave regime changes; higher port construction/maintenance costs; sedimentation/dredging issues in port/navigation channels; effects on key transit points; increased risks for coastal road/railway links; relocation of people/businesses; insurance issues</td>
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<tr>
<td>• Increased destructiveness of storms/storm surges</td>
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<td>• Changes in the wave energy and direction</td>
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<tr>
<td><strong>Precipitation</strong></td>
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<tr>
<td>• Changes in the intensity and frequency of extremes (floods and droughts)</td>
<td>Land infrastructure inundation; damage to cargo/equipment; navigation restrictions in inland waterways; network inundation and vital node damage (e.g. bridges); changes in demand</td>
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<tr>
<td><strong>Temperature</strong></td>
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<tr>
<td>• Higher mean temperatures,</td>
<td>Damage to infrastructure/equipment/cargo and asset lifetime reduction; higher energy consumption for cooling cargo; lower water levels and restrictions for inland navigation affecting the competiveness of estuarine ports (e.g. port of Rotterdam); reductions in snow/ice removal costs; extension of the construction season; changes in transport demand</td>
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<tr>
<td>• Heat waves and droughts</td>
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<td>• Increased spatio-temporal variability in temperature extremes</td>
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<tr>
<td><strong>Permafrost degradation</strong></td>
<td>Major damages in infrastructure; coastal erosion affecting road and rail links to ports</td>
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<td><strong>Reduced arctic ice coverage</strong></td>
<td>Longer shipping seasons-NSR; new shorter shipping routes-NWP/less fuel costs, but higher support service costs</td>
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Distribution of seaports in Europe according to physical setting

- Low estuarine ports
- Upper estuarine ports
- Open sea ports
- Inner river ports
Tidal levels at open seaports in the Mediterranean: Mean High Water Springs
Tidal levels at Atlantic and North Sea Seaports: Mean High Water Springs
The main railway line to Sochi in Black Sea will be in jeopardy if the fronting beach is eroded – this will be the case under 1 m storm surge and offshore waves with height \( (H) = 4 \text{ m} \) and period \( (T) = 7.9 \text{ sec} \) (red line).
Present normal conditions

Storm surge 1 m

Leont’ yev Model
Damage to railway connection from coastal erosion
Open sea ports: Availability of controlling wave data

A preliminary review has shown that even in one of the best studied European open sea ports (Barcelona) there is a scarcity of (field) information regarding the wave forcing controlling the port, despite the large spatial variability of the wave regime in the area.

(a) Available wave information along the Catalan coast (Sánchez-Arcilla et al., 2009) and (b) Uncertainty in the predictions (Weibull maximum likelihood) of the return periods of significant wave height (Hs) off the Spanish Mediterranean coast (Sánchez-Arcilla et al., 2008).
Multi-beam bathymetry of one of the Piraeus ports (Marina Zeas). Although the bathymetric detail within the port is amazing, there is no information on the bathymetry outside the port (which controls the characteristics of the approaching waves) neither on the open sea wave regime in the area.
Upper estuarine ports controlling factors:
Sediment availability

Approaches to the Hamburg (Elbe):
A lot of sediments to go around
Upper estuarine ports controlling factors

Studies show that variations in freshwater discharge, mean sea level and wind have a significant impact on storm water levels along the Elbe.

High water changes vary along the estuary.

Projections of high water levels in the river Elbe under a storm surge equivalent to that of 3.1.1976 and a mean sea level rise of 0.80 m (Schulte-Rentrop and Rudolph, 2013)
Low estuarine ports: controlling factors

Complex flow and sediment circulation patterns that depend on mean sea level, winds and riverine discharges

Changes may greatly affect port sedimentation

Annotated model output of erosion/accretion illustrating the complex sediment exchanges in Southampton Water. I. Townend, 2007
An interrelated world of transport

Surface Transportation Patterns
- Areas within 20 miles (32 km) of roads, railroads, or inland waterways

Ocean Shipping from Major Ports
- Width of line in proportion to tonnage of cargo carried:
  - 5 – 10 million metric tons
  - 10 – 20 million metric tons
  - 20 – 100 million metric tons
  - 100 – 200 million metric tons
  - 200 – 300 million metric tons
  - 300 – 400 million metric tons
  - 400 million metric tons or more
  - Passenger steamship lines

https://qed.princeton.edu/index.php/User:Student/World_Transportation_Patterns
Planning horizons and lifetime of port assets

Differences in port authority planning horizons and lifetime of infrastructure. (Koppe et al., 2012 IAPH case study)