Overview of long term sea level observation and analysis in the IHO context. Usefulness of historical data on prospective studies at IHO-TWCWG working group

Gwenaële Jan\textsuperscript{1} with IHO-TWCWG members\textsuperscript{2}

(1) Shom, IHO TWCWG chair
(2) IHO: International hydrographic organisation. TWCWG: Tide and water level and current working group
The IHO is an intergovernmental organization which was created in 1921. It works to ensure all the world's seas, oceans and navigable waters are surveyed and charted. It coordinates the activities of national hydrographic offices and promotes uniformity in nautical charts and documents. It provides guidelines to maximize the use of hydrographic survey data and develops hydrographic capabilities in Member States. 99 Members States.

Among Working groups and sub-regional committees (bathymetry, nautical charts, under keel clearance water, product specifications, etc.), TWCWG is created to meet tide water level and current items.

“if you can’t measure it, you can’t monitor it” said Dr Mathias Jonas, IHO Secretary General. “At the IHO we work with Member States to set standards so as to ensure information gathered about the marine environment is comparable and reliable.”
IHO function <-> TWCWG objectives

- To monitor developments related to tidal, water level and current observation, analysis, prediction, vertical and horizontal datums;

- To develop and maintain the relevant IHO standards, specifications and publications for which it is responsible in liaison with the relevant IHO bodies and non-IHO entities;

- To develop standards for the delivery and presentation of navigationally relevant surface current/water level information;

- To provide technical advice and coordination on matters related to tides, water levels, currents and vertical datums.

Focus on long data time series, IHO scope:
- **Sea level observation**: capacity building, methods, uncertainty control, meta data
- **Forecast** for applications water level, marine submersion, climate change
- **Impact**: marine frame, navigation, Chart datum via mean sea level
Why Measure Sea Level?

- Practical applications e.g. define vertical datums, safe navigation, constrain models, predict flood risks
- Coastal management e.g. sea level used to understand past and future changes in shelf and ocean conditions

Time-Scales and Causes of Sea Level Change

- Seconds to minutes: waves, tsunamis
- Hours to days: tides and surges
- Seasonal: surface heating and freshwater input
- Interannual: El Nino
- Long term trends: climate variability and change, vertical land movement

Maldives

Courtesy Yann Arthus Bertrand/Earth from Above/UNESCO

Src: Courtesy Thorkild Aarup IOC (talk at GLOSS and TWCWG#4 meeting 2019)
Selected highlights on historical sea level data inventories at IHO Tide water level and current TWCWG

Still to discover, recover

1700 1835 1840 1922 1950 1952 1960

Starting point for time series

- WG action keeping undeavour to share data knowledge, rescue, issues.
- Interest in data archeology information from organizations. Ex: IOC-GLOSS. Annual information from the 1st TWCWG. Catalyization since 2017 for data archeology.

1700 Dunkerque, 1835 Boulogne sur mer & Calais; Thesis 2017-2020 A. Latapy (ULCO, Shom)

Cooperation: cross-check, promote message guidelines, open discussion

- IHO-TWCWG interest in increasing knowledge from sites on treasures map: 1889 Hobart (AUS), 1838 (UK) Bristol, 1840 Irish Sea, others. Feedback on data, method, validation, achievement.
2. Background and Purpose

- **Purpose for the Project**
  - Construct the basis of various utilization on the tide observation record
  - Digitize One minute value from analog tide record paper

- **Background of the Project**
  - Needs for a permanent preservation of historical tidal records by Digitization
  - Needs for a historical tide level data Service to the public and the organization.
  - Needs for precise back data for the statistics to trace Sea Level Changes
  - Needs for improved utilization of tide level data

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1. Korean Tide Observations

- **Tide observation status**
  - Mokpo is the first tidal station built in 1952 (in Korean war), and now 44 tidal stations are in operation
    - West coast: 19 (Mokpo, Dawheukseom, Younghwang etc.)
    - South coast: 17 (Bulsan, Kodzuldo, Mosan, etc.)
    - East coast: 8 (Dolpo, Mokra, Ulsando etc.)
  - Both analog and digital tide observation equipment are in use complementary since 2003 at every tidal station.
  - Tidal Data can be accessed on the web and the ARS

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1. DB Construction Processes

<table>
<thead>
<tr>
<th>Scanning</th>
<th>Digitizing</th>
<th>Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan</td>
<td>Value Inspection</td>
<td></td>
</tr>
<tr>
<td>Scan Quality inspection</td>
<td>Mechanic al Error inspection</td>
<td></td>
</tr>
<tr>
<td>Graph Extraction</td>
<td>Referential inspection</td>
<td></td>
</tr>
<tr>
<td>Digitization</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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2. Step 1: Scanning

- **Scanners Used**
  - 3 types of scanner were used to handle various paper type
  - Overhead, flatbed, Wide format scanner were used
Historical sea level (meta)data inventories; digitalized data: Project Construct tide observation record DB, Inhwan Moon, Korea Environmental Science & Tech Institute Inc.) Outcome TWCWG#2, 2016)

2. Step1: Scanning

- Preparation of scanning
  - Classification by Paper Size
    - 34 types of paper size were classified by the specification of recording paper.

II. DB Construction Steps

- Type Reclassification by Properties
  - Most used types are A2, A3 (continuous type)

<table>
<thead>
<tr>
<th>Type classification</th>
<th>Code</th>
<th>Digitizing method</th>
<th>number of type</th>
<th>Amount/day</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large type</td>
<td>A0, A1</td>
<td>Digitize after downsizing scan file size as the original is too big.</td>
<td>2</td>
<td>6,888</td>
<td>3.1</td>
</tr>
<tr>
<td>continuous type</td>
<td>A2, A3, A4</td>
<td>Digitize after securing 24 hours of tide record are included in each page</td>
<td>3</td>
<td>145,219</td>
<td>66.7</td>
</tr>
<tr>
<td>Individual type</td>
<td>A5, A6, A7, A8, B1, B2, B4, B5, B6, B7, B8, B9, C7, C8, C9, D1, D2, D3, D4, D5</td>
<td>Digitize after assigning the code on handwritten scale and record starting time by pages</td>
<td>20</td>
<td>55,183</td>
<td>25.3</td>
</tr>
<tr>
<td>Y-axis curved type</td>
<td>A9, B3, C1, C2, C3, C4, C5, C8, D6</td>
<td>Digitize after reconstructing rectangular coordinates by curvature correction of Y-axis curve.</td>
<td>9</td>
<td>10,107</td>
<td>4.9</td>
</tr>
<tr>
<td>Total</td>
<td>34</td>
<td></td>
<td>217,797</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

3. Scope and Schedule

- Scope of the project
  - Record amount
    - Coast | No. of Station | Amount | Digitized Data Count
    - West Coast | 14 | 254 | Books | Pages | 120,479,040
    - South Coast | 17 | 393 | 134,131 | 193,148,640
  - 31 Tidal Stations produced 647 books, 217,797 pages(days) of tide records were found
  - Total 1 min. Data : 313,627,680

- Project Terms
  - July 2009 ~ Dec. 2009 (6 Months)
**Historical sea level (meta)data inventories; digitalized data: Project Construct tide observation record DB, Inhwan Moon, Korea Environmental Science & Tech Institute Inc.) IHO-TWCWG#2, 2016**

### Achievement

#### Expand Coverage of Tidal Information Services
- Historical tide data is provided on the web
- Expect significant savings of time and resources for Management, Search, analysis and statistics of tide information

#### Infra for Tidal data utilization constructed
- Expect Increased Information utilization through the Digitization of Analog Tide Records
- Improve the accuracy of statistics and Tidal analysis Through the creation of 1 minute Tide Records
- Expect an active exchange of information between Related agencies, academies and Research Groups

### Achievement

**Systematic Achievement**
- Systematic Frame Constructed For digitizing analog Tide Observation Records
- Built an image processing technique for digitizing Tide Observation Records
- Secure digitizing methodology developed for the various types of recording paper and the type of errors
Historical sea level data inventories; Methodology for transfer of paper records to digital data; Auxiliary historical archives relative to sea level

**Open issue: Data rescue**

- Preserve the historical scientific heritage.
- Improve the knowledge on trends in sea level components and on the coast vulnerability.
- Identify and study the extreme sea level surges.

Contact: Yann.Ferret@shom.fr

**Data rescue**

- Data available since 1700 for Dunkirk; 1835 for Boulogne-sur-mer and Calais.
- Data: tide data (tide charts and handwritten ledgers).

Contact: alexx.latapy@etu.univ-littoral.fr

**Evolution of the coastal zone**

Source: workshop IHO-TWCWG#2 (2017); G. Jan (Shom)

Courtesy of Y. Ferret, A. Latapy (Shom, ULCO)
**STATE OF THE INVENTORY OF SHOM ARCHIVES**

**HOW MANY DOCUMENTS IN SHOM ARCHIVES**
- More than 50,000 documents identified and accurately inventoried
- about 50% have already been scanned
→ But … Still thousands of documents to carefully inventory/scan!

**GEOGRAPHICAL EXTENT**

**France (Fig. 3):**
- about 1,000 years of cumulated sea level measurements, ~ 300 sites
- Total duration per site ranging for few days/weeks/months (observations for sounding reduction purpose) to several decades
- Longest time series correspond to historical tide gauge network (Fig. 2)

**Around the world (Fig. 3 & 4):**
- about 470 years of cumulated sea level measurements, ~ 240 sites
- Mainly short duration observations, but some « long » time series (fig. 4)

**Figure 3: Number of locations with sea level observations according to the total duration of the measurements from Shom archives**

**Figure 4: Partial view of the spatial distribution of the sea level data around the world, from Shom archives**

Workshop sea level data archeology 2020: Possible additional knowledge from KHOA, Norway, Finland, Denmark, Germany, Japan & volunteers at IHO-TWCWG

Could complete the view

Figures & left panel from Y. Ferret, V. Donato Shom (IOC GLOSS, IHO TWCWG joined session 2019)
Increased emphasis on data centricity in the international community

• Today, some MS are doing sea level archeology (not all the WG~10) but there is a big potential from these scarced data to be « rescue »; scarced how?

• Data archeology science profile is made of prompt / ad hoc (geographic) partly studies due to scarcity historical data, time and cost consuming. This is a typical case where data knowledge shared provides a large profit for science.

• Today, one TWCWG track to promote it : distincts projects but common data set + gathered at IHO-WG exchanges
Selected results at IHO-TWCWG: Water level trend

Member States are conducting projects using sea level long term time series and results are numerous dealing with tide, water level slope at a national level, natural risk and climate evolution. Long term time series brought important information changing sometimes the game thanks to the knowledge enrichment, vertical or meta data, quality data update. For ex: the Norway: Different views on a common time period: 1960 to 2010 and 1984 to 2014.

“Sea Level Change for Norway Past and Present Observations and Projections to 2100”

1/ A rise in relative sea level are observed in Norway, After correcting the rates for glacial isostatic adjustment, SSH rates are positive at all tide gauges. Coastal average is 1.9 and 2.4 mm, respectively, for the 2 periods. Close to the global average rates for the 20th century. Pattern is governed by the vertical uplift rates. Quantifying the probability distribution of levels remains difficult because information is lacking. Ice sheet contribution might have a skewed distribution, which would mean values in its upper tail would be quite large.

2/ A fall in observed sea level: land uplift due to local ice mass losses. Pointing the need to improve data quality (errors, common data set) (Ref: H. Sande et al. 2019, TWCWG#4) Rates are sensitive to the selected study period, which is indicative of strong inter annual to multi decadal variability in the tide gauge records.

Selected results at IHO-TWCWG tide pattern, Kuroshio, typhon

KHOA (TWLWG1, 2010)

**Technological breakthrough context**

We all face to the question of continuity in data referencing, data uncertainty in order to insure consistent time sery
Going on tide Long term sea level data application to tidal analysis & prediction

The longest the validated time series is, the best is the prediction (cf; From a time sry, FFT, jump in spectral domain, Laplace, Lord Kelvin, Doodson et al.)

& Harmonic constants & Spectral split

=& Better tide prediction (cf; IHO recommendation on uncertainty [cm], uses cases requirement. Ex: navigation)

Src left panel: Harmonic slides: Chris Jones (UKHO) TWLWC2

Src: Shom (Fr), tidal analysis zoom on semi diurnal spectral split

• + Nodal factor contribution to tidal water level (several years long)
Applications and knowledge products from recovered data; Cooperation perspectives

Analysis: need to know what methods are used, what constituents are included; for what use.

Data sets: Continue to collect common data set online for interesting stations with a variety of tidal phenomena.

Different approaches in different countries.
Different data selections
How to cope with different long term effects such as trends in the analysis?
Come up with guidance or recommendations on harmonic analyses. Discussions included choosing constituents.

Message pushing open doors:

Cooperation perspectives; a reason why open access to long time series from & for international community would fill a need with the best of energies.
IHO TWCG work plan relative to sea level long time series

- **Compare tidal analysis methodologies using long term data sets**: Develop a work plan with milestones to add new test data sets and conduct standardized analysis.

- **Compare the tidal predictions generated as a result of analysis of a common data set using different analysis software**.

- **GLOSS and TWCG outcomes**: TWCG4 and GLOSS pair meeting highlighted 3 strong common points of interest: The data (measurements data, quality control, data management), the capacity building and data archeology actions. This synergy can in the future promote and strengthen the knowledge communication and cooperation.

A significant discussion was heard on capacity building of IHO and how GLOSS group of experts could assist with those efforts. GLOSS highlighted their water level manuals which are located on their website as a potential contribution. Both groups agreed that greater partnering in capacity building would benefit both groups.
Long term sea level data application to Chart datum for navigation & Marine submersion

- Vertical level or surfaces of reference (Almost all MS of IHO TWCGW are conducting a vertical ref level (MSL often starting point to derive surface of reference LAT, CD, Hydrographic zero) recommendation time seria > 30 years depending on the need for application.


- TWCGW keeps in mind the application to statistics return period. Extreme value is a probability function distribution a game changer, historical data could be also.

- Historical data achievement would be extremely benefit (cf; slope better fit thanks to scarced data, old, were there is a lack of data).

- One direct use: Marine submersion, Past storm and from this history teaching, forecast the plausible future storm and coastal impact in the frame of climate change.
Data archeology item written in TWCWG actions plan since 2013.
Continuous interest in IOC-GLOSS outcomes, PSMSL, REFMAR, and more,
GIEC, freely shared data by IHO Member States

Extant questions at IHO-TWCWG:
data consistency: measures’ uncertainty,
detailed method to digitize + analyse
historical data & its meta data

Collective knowledge
Framework
Program
Issues
2020
2019
2018
To go further in documentation:

- Intergovernmental Oceanographic Commission (UNESCO)
- Manual N°14 On Sea Level Measurement and Interpretation, Volumes I – IV
- PSMSL (Permanent service for mean sea level)
- ESEAS (European Sea Level Service)
- GLOSS (Global Sea Level Observing System)
- IHO Circular letters : available online on a lot of topics
Workshop on sea level data archeology

Thank you

A collective marine historical data bank for science? Existing? Gather selected historical data in a science collective bank for several gauges for research in climate, land vertical trend, water level trend, vertical reference, etc. Inform scientific community. Could benefit to science so for local executives and potential financial support.

Ocean current, coastline, atmospheric data archeology?