Improving the vertical datum at sea: Towards vessel navigation in 3D space

Benjamin Hell [1, 4]
Jonas Ågren [2]
Lars Jakobsson [1]
Wilfried Ellmer [3]

1: Hydrographic Office, Swedish Maritime Administration, Norrköping (Sweden)
2: Geodetic Research Division, Lantmäteriet, Gävle (Sweden)
3: Hydrographic Office, Federal Maritime and Hydrographic Agency, Rostock (Germany)
4: Corresponding author, *benjamin.hell@sjofartsverket.se*

Vessel navigation today

Problem:
Large (dm) uncertainties in
- Geodetic height of datum at sea
- Hydrodynamic sea level
- Dynamic vessel draft

This makes it difficult to accurately derive under keel clearance from chart soundings.

Workaround:
Navigators add extensive safety margin.

Hydrographic surveying yesterday and today

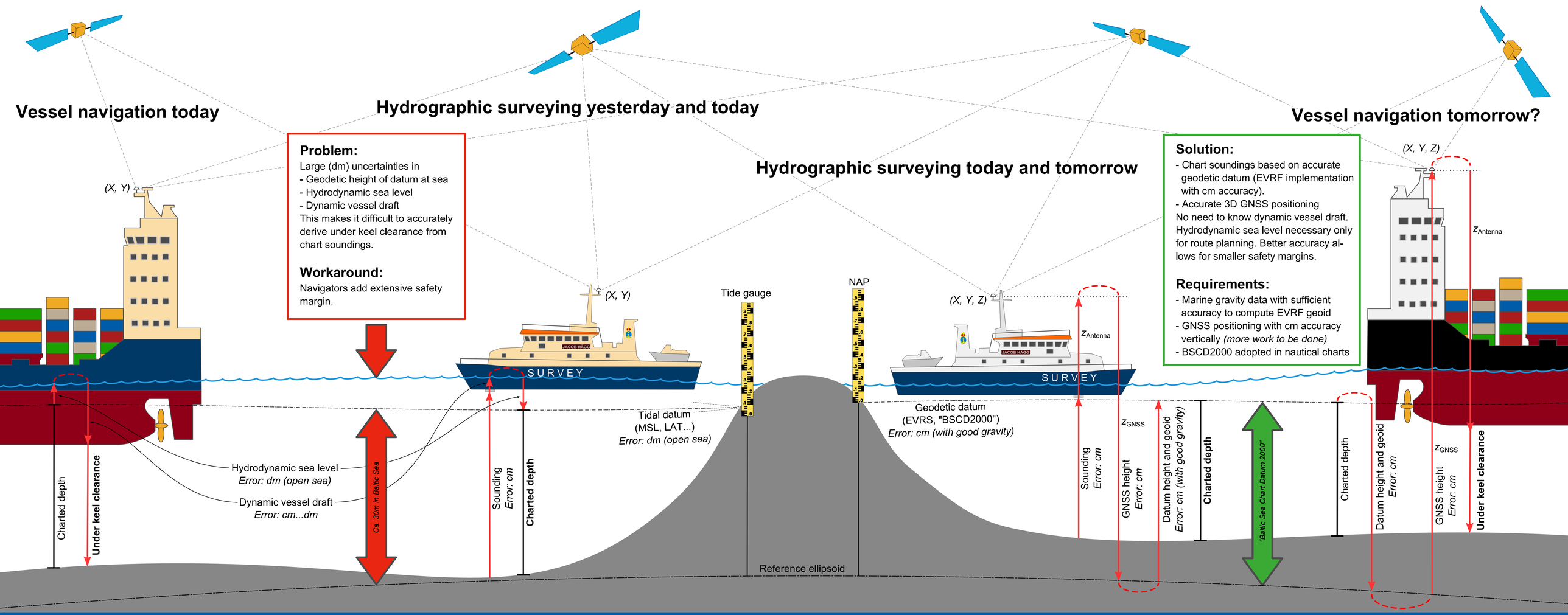
Hydrographic surveying today and tomorrow

Vessel navigation tomorrow?

Solution:
- Chart soundings based on accurate geodetic datum (EVRF implementation with cm accuracy).
- Accurate 3D GNSS positioning

No need to know dynamic vessel draft. Hydrodynamic sea level necessary only for route planning. Better accuracy allows for smaller safety margins.

Requirements:
- Marine gravity data with sufficient accuracy to compute EVRF geoid
- GNSS positioning with cm accuracy vertically *(more work to be done)*
- BSCD2000 adopted in nautical charts



Today, the vertical datum of depths in nautical charts is a hydrodynamic water surface, such as Mean Sea Level or Lowest Astronomical Tide. Such surfaces are derived from coastal tide gauge measurements and hydrodynamic models, with an uncertainty typically on the order of decimeters or meters. Both hydrographic surveying and vessel navigation are relative to this vertical datum, applying appropriate safety margins due to uncertainties in e.g. datum, tide and vessel dynamics, to ensure sufficient under keel clearance.

For the future, the Baltic Sea states plan to adopt the European Vertical Reference System (EVRS) as chart datum. EVRS is no hydrodynamic model, but the surface of constant gravity potential through Normaal Amsterdams Peil zero, resembling the geoid at sea or the idealized water surface – i.e. without tide, currents, weather and assuming constant water density. To determine the geoid at sea, accurate marine gravity measurements of sufficient spatial resolution are necessary. Such measurements will be carried out within the FAMOS project.

This can have tremendous benefits for safe navigation at sea: Provided that the geoid – and therefore the vertical datum – is known with an uncertainty on the order of a decimeter or better, and that future GNSS positioning at sea allows for a vertical uncertainty on the same order of magnitude, a vessel could determine its position in 3D space with high accuracy, virtually independent from the actual sea surface. It would become straightforward to accurately derive under keel clearance from charted depths and vessel dimensions. The approximated safety margins conservatively applied today could be decreased significantly, and vessels with larger draft could navigate in a given fairway without increasing the risk of grounding.

Given the current trend of increasing ship size to optimize costs for maritime transports, the economic consequences in a shallow region sea such as the Baltic Sea could be enormous.