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Bathymetric data processing for multi-use products

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Statistical MBES Data Processing

Efficiency through mathematics

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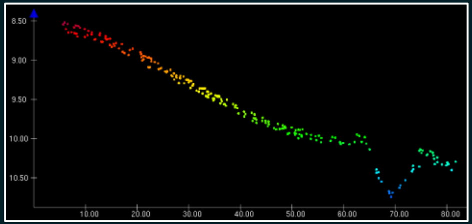
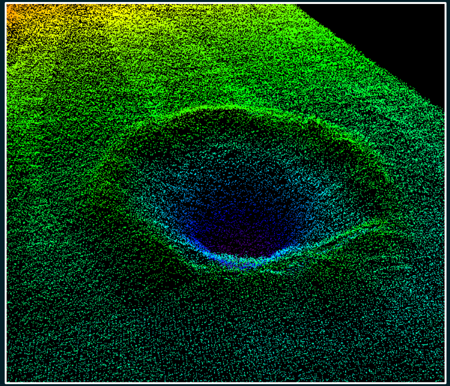
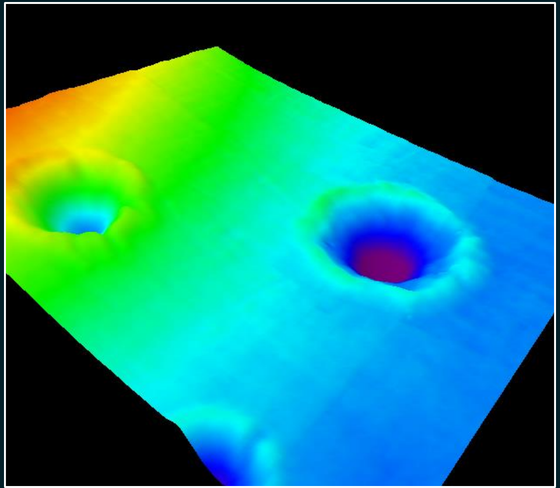
Points vs Point Clouds

A single point can't be trusted but a point-cloud tells a story







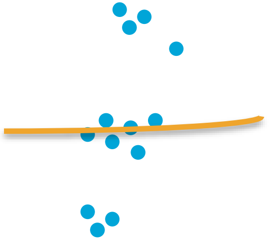
A sounding is NOT “the depth”. It is just one measurement of the depth near a point in space.

Sounding TPU is only an *apriori* estimate – it is not empirical

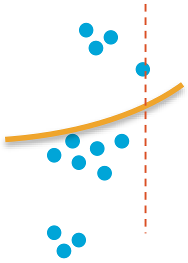
Can we compute a depth that tells the truth?

Building a better understanding of depth

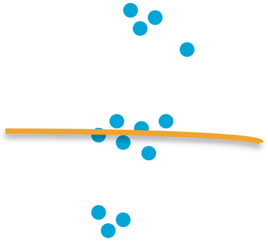
Statistical estimates are not always "safe"



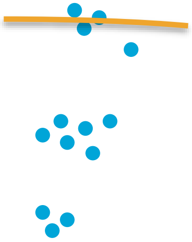
Mean Surface



Distance weighted mean surface



Median surface

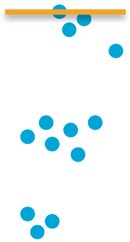


CUBE – if we setup correctly!

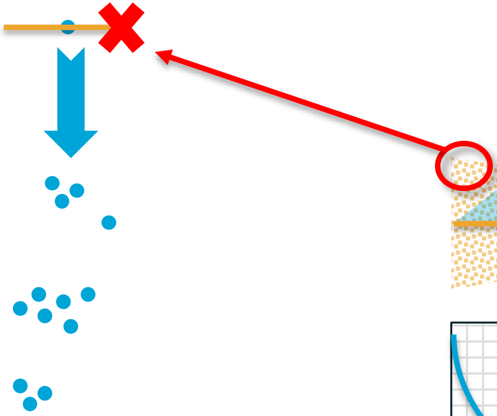
All surfaces will look similar, when viewed at sufficiently small scale but features of navigational or scientific significance may not be expressed

Why generate an depth estimate?

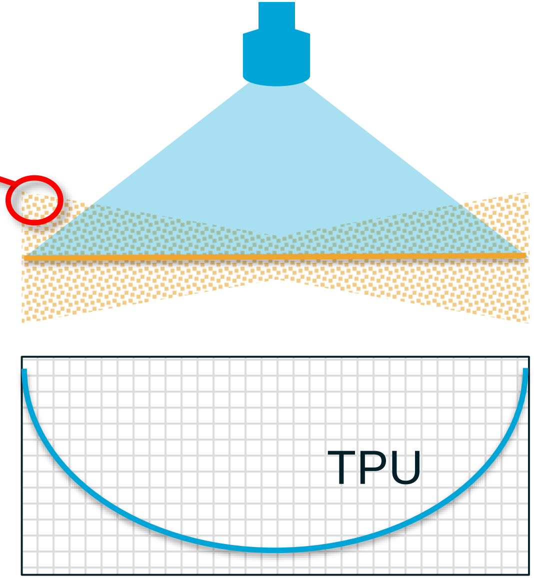
Because shoal-biasing is systematic selection of bad data



Shoal-bias works in this case



What about with noise?



Shoal biased data is selected from the **worst quality soundings** in an MBES swath.

It ignores features of scientific interest and cleaning data is **very time consuming**.

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CUBE Fundamentals

A better way to build an estimate

What is CUBE?

A point estimator of depth and uncertainty from redundant data

- Combined Uncertainty and Bathymetry Estimator
  - In the future = CHRT (CUBE with Hierarchical Resolution Techniques)
- A mature tool from NOAA/UNH by Brian Calder from 2000 onward
- Used by NOAA and NAVO in production since 2005
- Outputs 2D geospatial dataset with point attributes:
  - Depth Hypothesis (preferred) derived from a naive Bayes approach
  - Depth Uncertainty
  - Hypothesis count
  - Hypothesis strength
- Nodes are regularly spaced (CUBE) or systematically placed according to data density (CHRT)
- There is no horizontal uncertainty, only depth uncertainty

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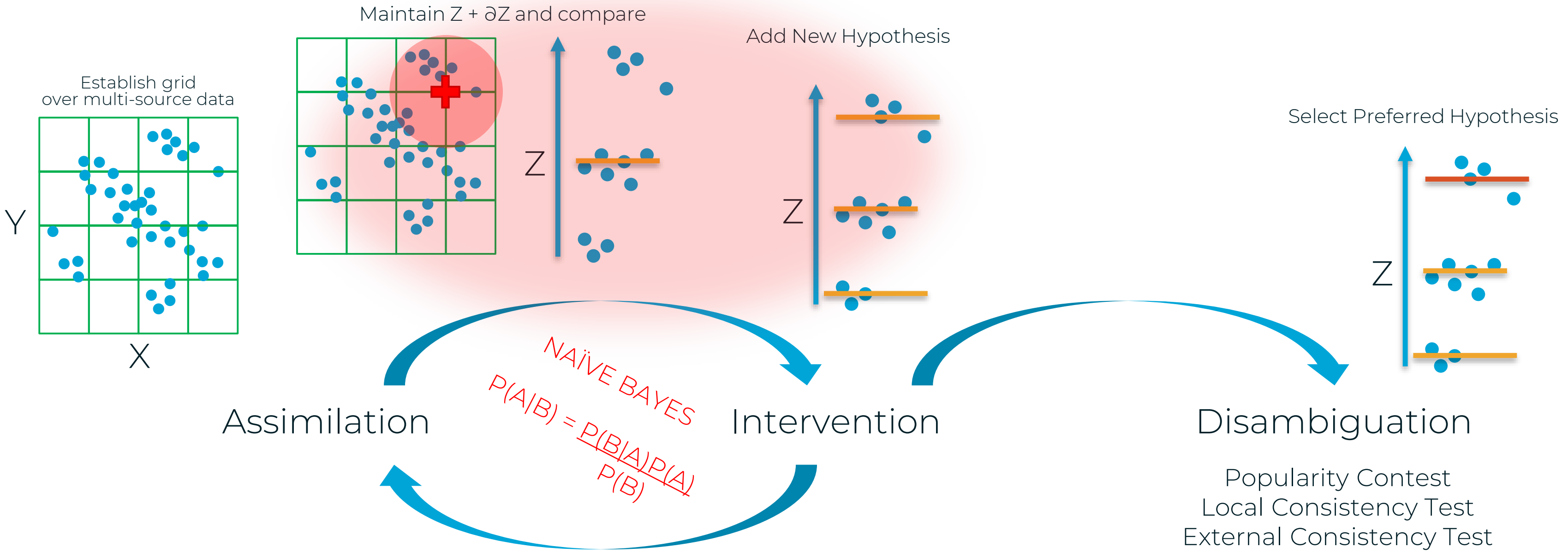
How does CUBE work?

Three key stages



Popularity Contest
Local Consistency Test
External Consistency Test

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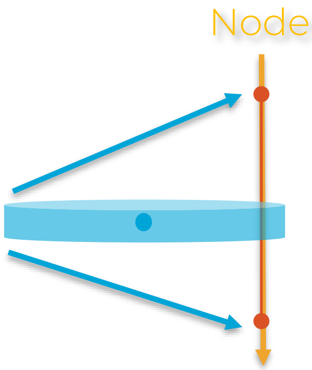
CUBE key parameters

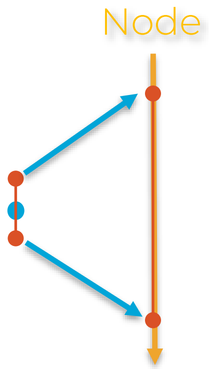
Bad inputs = bad output



Horiz_Error_Scalar

Scale the THU of a sounding to de-weight vertical influence at the node location.

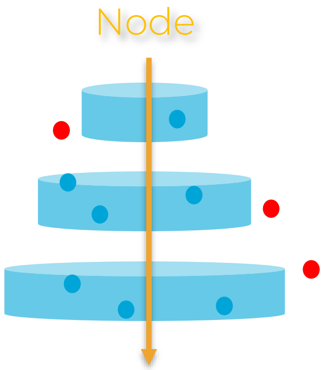
default = 2.95
(for 99% CI vs NOAA 1.96)



Distance_Exponent

Scale the TVU of a sounding based on distance to node.

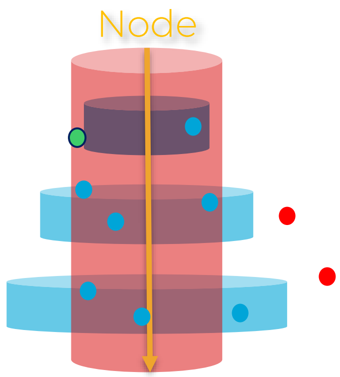
default = 2.0
(for inverse square relationship)



Capture_Distance_Scale

Scale based on estimated depth for how far to look for data from the node.

default = 5% of depth
(for IHO Order 1a but recommend 2.5% for IHO SO)



Capture_Distance_Minimum

Min value (m) for distance from node to gather data.

default = 0.5m
(recommend surface_res/√2
So no sounding left behind!)

Surface Resolution is also a critical factor. Recommended maximum node spacing = 0.5 x feature size

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CUBE output

Statistically valid data, saves time, supports other uses

- CUBE produces a surface of “best estimate” but is not necessarily the truth. However, it does output uncertainty for each node so you know how “true” it is likely to be.
- Full subset inspection is still necessary for charting surveys!
- BUT edits are only necessary where, in the surveyor’s opinion, they are required. If CUBE is well parameterised, edits will be few (lots of edits means a bad setup!)
- 10- to 30-fold time savings are realised.
- Supports statistically reliable products
    - Shoal bias navigation surface in risk areas by subtracting 95% CI layer from depths, rather than by selecting golden soundings – the result may actually be shoaler than shoal biasing and is more rigorous.
    - Add uncertainty to model boundary conditions for oceanography.

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Practical CUBE

For surveyors and scientists

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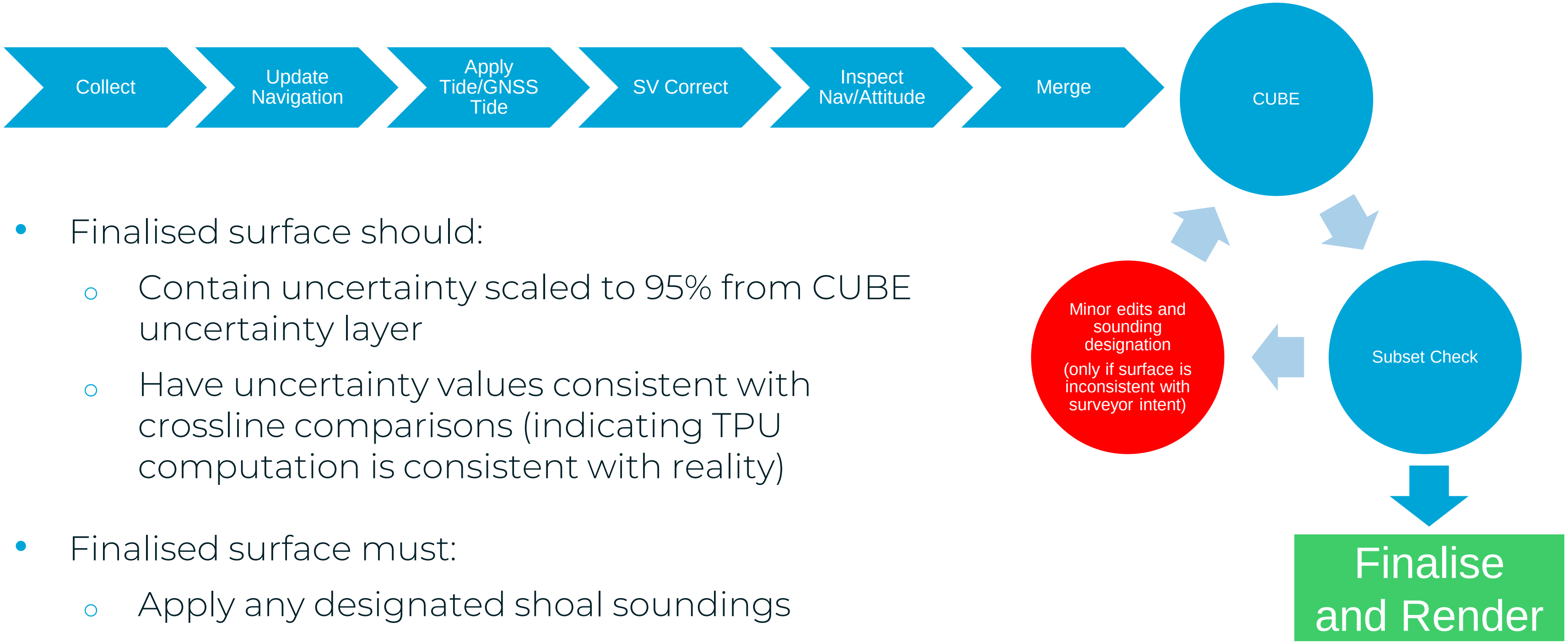
Practical CUBE

Collector workflow – charting product outputs



- Finalised surface should:
  - Contain uncertainty scaled to 95% from CUBE uncertainty layer
  - Have uncertainty values consistent with crossline comparisons (indicating TPU computation is consistent with reality)
- Finalised surface must:
  - Apply any designated shoal soundings

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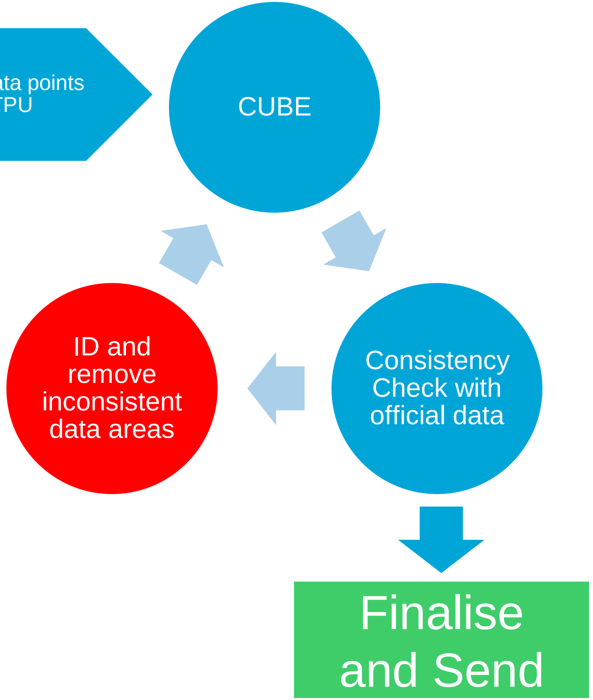
Practical CUBE

Science Workflow – automated aggregated data outputs



- RAW sources can be LiDAR, MBES, SBES, SDB etc. as long as they have XYZ and Vertical/Horizontal TPU.
- Finalised surface should:
  - Contain uncertainty scaled to 95% from CUBE uncertainty layer
  - Have uncertainty values consistent with junctions to surrounding official data
- Finalised surface must:
  - Apply any designated shoal soundings
  - Be in an open format (such as BAG, NetCDF etc.)
  - Be marked as NOT FOR NAVIGATION

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References

CUBE, CHRT and related papers of interest (added since workshop)

Original CUBE paper:

B. R. Calder and L. A. Mayer (2003) 'Automatic processing of high-rate, high-density multibeam echosounder data', Geochemistry, Geophysics, Geosystems, vol. 4, no. 6, p. n/a–n/a, Jun. (https://scholars.unh.edu/ccom/110/)

Original CHRT paper:

B. R. Calder and G. Rice (2011) "Design and implementation of an Extensible variable resolution Bathymetric Estimator," in PROC. U.S. HYDRO. CONF, pp. 25–28. [Online]. (http://ushydro.thsoa.org/hy11/0428P_01.pdf)

Parellelised CUBE-like processing on a cluster:

Venugopal, Rohit and Calder, Brian R., "Hydrographic Data Processing on a Robust, Network-Coupled Parallel Cluster" (2012). 6th International Conference on High-Resolution Survey in Shallow Water. 667. [online] (https://scholars.unh.edu/ccom/667)

CUBE User's Manual (annexes were never completed but very useful nonetheless):

Calder, Brian R. and Wells, David E. (2007) "CUBE User's Manual“, Center for Coastal and Ocean Mapping. 1217. [online] (https://scholars.unh.edu/ccom/1217)

Empirical uncertainty estimation:

Lawes, Geoffrey. (2013) 'Architecture independent vertical TPU estimation for multi-beam sonar processing', in PROC. U.S. HDYRO CONF. [online] (http://ushydro.thsoa.org/hy13/pdf/0327A_06_51.pdf)

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