Arctic Grid Analysis

Regional Grid Proposals Extracts.

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1 Introduction.

This report details the process and outputs of the Arctic Grid study carried out by IIC technologies for the Canadian Hydrographic Service (CHS) between November 2019 and March 2020.

In this extract from the full report we detail the outputs of the research relevant to proposals for future cooperation within the region and some of the scope and content it would require.

An executive summary is included which introduces a broad summary of findings and recommendations.

The emphasis of the project, documented in this report is to positively contribute to the process CHS has embarked on in moving to S-100 framework product specifications in order to support safe and efficient navigation within the region. An additional goal is to contribute to the broad range of auxiliary applications for marine geospatial data articulated within the S-100 framework supporting environmental and scientific goals, and to encourage enhanced cooperation between Arctic stakeholders – practical implementations and technical means contributing to this are of profound interest to groups such as MSDIWG and UN-GGIM.

A discussion of the pros and cons of a grid approach in general is beyond the scope of the current document. The use of grids to rationalise data production efforts and provide a common basis for many different thematic products is increasing globally, and the emerging S-100 framework offers an opportunity to rationalise current portfolios. Grids with common boundaries between resolutions and regular subdivisions offer an abstract structure on which many layers can be placed and offer benefits for data production and its ongoing management in the future.

2 Executive Summary

- The Arctic poses unique challenges for navigation and vessel operations within the region. These are primarily (but not completely) climatic in nature. There are additional constraints including meteorological, logistic, directional and communications which pose serious challenges for any vessel in the region.
- There is a growing requirement in the Arctic for scientific research and environmental protection. This is unprecedented and increasing and co-exists with a complex and evolving regulatory environment in many of the areas of interest in the study.
- The nature of navigation and how charts and publication support navigation is fundamentally different in many ways within the Arctic, mainly due to the more complex unknowns in the hostile environment and the uncertainty/paucity of available data to support planning and voyage operations.
- The proposed grid is a canvas on which many product specifications could be defined but the most fundamental of these is S-101 ENCs (and legacy S-57 ENCs during the S-101 transition period). Other S-100 products such as S-102, S-104 and S-111 will also be produced against the same grid but the primary challenge, and therefore the greatest focus is how to accommodate the transition to a gridded scheme for ENCs.
- It is therefore probably worth at this stage considering how such a transition to grid can be achieved and how legacy S-57 ECDIS are to be supported during the dual-fuel ECDIS transition period. Recent activity in the IHO working groups contributes to this. A Summary paper has been included as an annex to this report which was submitted following the last S-100WG and contains information on how the proposed S-100 ECDIS will work and some of the likely impacts on data producers.

- There is a long established history and tradition of cooperation between states in the Arctic and the stated goal of the project has been to suggest gridded scheme(s) that might harmonise activities in the region. There is a broad range of approaches and history to grid schemes for the participating nations. They are at different points in their journey towards a gridded schemes and a superset of these has been used to generate two main suggestions for gridded schemes that would extend the CA proposed grid in a way likely to achieve consensus amongst stakeholders. These suggestions are aimed not just at providing a grid scheme to support primary ENC charting but also ancillary uses of marine geospatial for scientific/environmental and regulatory purposes.

3 Regional Proposals

In this section a proposal for a grid covering the Arctic region is documented. This proposal is considered from the point of view both of the current providers within the region as well as taking the existing Canada proposal as a starting point – the aim has been to balance the existing CA scheme with something that will appeal to the RHC members and associate members.

3.1 Drivers

In order to make a proposal which has the best chances of success within the Arctic members of the regional commission it is necessary to understand the drivers for cooperation as well as having a basic understanding of both the political, geographic, legal/regulatory drivers and trends of the region as a whole

The arctic region has a history and reputation for cooperation, despite the many opportunities for tension and conflict which exist there. Although a number of unagreed boundaries and claims exist in the region the overwhelming activities are ones designed at encouraging cooperation of the participants and members.

Geopolitical regime – unlike Antarctica which has a single treaty governing many activities within it, and its enjoyment of a scientific protected area the Arctic shows all the signs of being a productive, working region for many years to come. The existence of two acknowledged sea routes, the NWP and NSR together with tourism and hydrocarbon resources means there is likely to be a substantial amount of interest and activity centred around commercial, environmental and scientific activities in the future.

Regulatory regime and geopolitical background

The Arctic is governed by a number of treaties between member states within the region. Recently the Polar Code has been adopted which provides additional environmental protections across the region A single Arctic treaty is frequently discussed and raised but currently the member states within the region determine largely the regulatory regime for its users.

The main governing conventions in the region are, therefore, UNLCOS' general provisions for delimitation of marine zones, and its obligations for protection of the marine environment are highly relevant. IMO SOLAS is the predominant shipping convention for the region, as well as other IMO instruments particularly:

a. Enhanced Contingency Planning for Passenger Ships in areas remote from SAR
b. Guidelines for Voyage Planning for Passenger ships operating In Remote Waters
c. Guidelines for Ships Operating in Polar Waters
d. The Polar Code

Member states often implement extra legislation over and above the bounding conventions, an example being the ice navigation framework for Canadian waters. This, as previously noted, is extensive and detailed. Other marine zone requirements are implemented by member states within the confines of their UNCLOS defined zones as well as regional treaties covering e.g. pollution and SAR.

Shipping and Navigation

From a shipping point of view the likelihood is a steady increase in shipping activity, both surface4 and subsurface in commercial, regulatory and defence sectors – hence an increased requirement for the highest quality navigational charts, publications and auxiliary aids possible given the often extreme conditions predominant.

The Arctic also has a large (and increasing) amount of scientific activities carried out under various agreements and conventions. Climate change and the research associated with it has participated an explosion of activity in the region for exploration and analysis.

Environmental Protection

Many of the activities within the region, and the driving force for much of the change seen in recent years is environmental protection, its associated regulation and scientific exploration in support of environmental protection. There is a significant level of uncertainty about the Arctic's future both from an environmental and economic point of view as regards the scope and content of the activities there but the availability of, and access to, high quality marine geospatial data for both navigation and in support of auxiliary activities is one of the defining characteristics of the region. It is interesting to note the progression of SDI structures in the Arctic in support of these trends.

The main Activities of the region therefore remain:

- Shipping and Logistics
- Tourism
- Mining
- Fishing
- Scientific Exploration

3.2 Critical Success Factors for a regional proposal

A proposal for a regional grid across the Arctic is perfectly in keeping with previous activities such as the previous Arctic SDI initiative and would be in keeping with current charting activities in relation to S-100's "Decade of Implementation".

The adoption of S-100 is encouraging all member states to review their production capabilities in the light of multiple product specifications covering their waters and many are considering (or have already adopted) a grid system in order to simplify their production processes. Certainly the implementation of S-100 encourages states to promulgate a far broader set of standardised data and this broadening is a natural source for collaboration and working for mutual benefits with other states in the region.

So, in a sense the Arctic region is one where member states have many common interests, common challenges and a common sense of purpose to contribute to the development and preservation of a unique environment. To that end a unified grid system which can cover not only navigational activities but also auxiliary uses of marine data has a better chance of success than one purely predicated on navigation. In order for such a proposal to success it would need to:

a. Be equally familiar to all participants. If common factors amongst all stakeholders are observed then they should be used.

b. It should be politically and geographically as neutral as possible. Anything which expresses a preference, or appears to favour any one state in the region is unlikely to succeed in the long term
c. It should serve long and short term goals. S-100 implementation and charting in support of safe shipping is an obvious one in the hydrographic realm. The increase in scientific research and monitoring is another. In general the appeal should be as wide as possible and capitalise on both S-100 and the possibilities offered by other initiatives and international groups.
d. Any scheme should cover the entire region without gaps and include a number of subdivisions at different resolutions.
e. A scheme should be as flexible as possible to allow for states within their own waters to adapt it to suit their local requirements and to meet their regulatory needs

Any proposal is likely to require refinement and agreement from the core stakeholder participants. It is unlikely that an initial proposal will simply be accepted with all of its detail. What is important in an initial proposal is to promote the "message", that a combined gridded scheme:

a. Works for the primary purpose of chart production.
b. Establishes a common framework not just for SOLAS purposes of safe shipping but for many different uses of data moving into the future
c. Meets future requirements for use of marine geospatial data in the broader sense – that it resonates with the aims of other groups such as MSDIWG and UN-GGIM
d. Will promote cooperation between members in the region for the long term. This cooperation gives a common canvas on which to paint future joint activities.
e. Is well thought out, feasible, practical and capable of success given the many constraints on all members in resource terms.

3.3 Scope of proposal

3.3.1 Where are the boundaries?

The geographic scope of the boundary of the arctic "region" itself is complicated and would need some consideration to establish what extent is likely to have the best chance of success in a regional proposal. Unlike Antarctica where the Antarctic Convergence and Southern Circumpolar current form a natural boundary no such natural boundary or delimitation is really possible within the Arctic. Various definitions such as the Arctic circle or other limiting latitudes may not be appropriate in this case.

The Polar Code definition of the Arctic, an IMO derived definition, is a well established one, although irregular as it involves individual named points referenced within the code.

The choice of scope is a crucial one and intimately related to whether the aim of the proposal is to cover just the High North (i.e >75 or 80°N) or whether to use the coastal Arctic (>60°N) as the boundary. This is related to the issue of existing ENC coverage from all the member states and whether the regional proposal is asking them to rescheme existing ENC data for the area in line with the new gridded scheme (as noted earlier in this report, such rescheming of S-57 data may be required in order to support legacy ECDIS during the transition period to S-101). Currently little concrete data producer advice exists but recent S-100WG meetings have begun to define this and documentation is available on the subject.

Ultimately a proposal can be adapted in terms of its geographic scope – although defined for a large region, probably to a limiting latitude the actual extents in which activities such as charting, scientific research or other activities (S-10X production for example) could be decided subsequent to acceptance of the grid in principle. All the proposals here could be adapted for either a manually defined boundary or a limiting latitude model.

Figure 1: Arctic definition from IMO Polar Code

3.3.2 Chart production / Scope of Activities

It is important as part of any joint proposal to examine the scope of activities proposed. These could include.

- Adoption of Grid by ARHC members for production of primary ENC charting – covering both S-57 and S-101 (co-production as detailed in the Annex to this paper)
- Production of other S-100 data products by voluntary consensus – e.g. S-121, S-411, MPAs etc..
- Use of grid for ancillary purposes such as environmental protection, scientific research etc. A non-IHO, neutral framework could be co-defined (through the RHC or through OGC for instance) which would allow the grid boundaries to be used for non-IHO domain activities and encourage take up within both national and regional frameworks.

Should some degree of "joint" chart production be part of a proposal? By way of example, the EAHC produces combined small scale charts of the SCS as part of their regional cooperation activities. Such a proposal could form part of the grid system and could encourage participation by member states by tying production of tangible data products to adoption of the grid scheme. This would also help to address the “migration” issue of existing coverage by providing an immediate data production capability at some scales and some mutually agreed areas.

Within the region there are areas of extremely sparse data and areas where small scales could be jointly produced between member states and offered for distribution through dedicated channels.

Small scale charts showing the many administrative areas and regulatory zones could be easily co-produced as the data is authoritative and would serve as a backdrop for future ENC production. Member states could then produce their own larger scale navigational charts in their own waters/EEZ as national schedules and priorities dictate.

A dedicated producer code could be sought from the IHO (“AC” is currently available) and assigned to the regional commission for production of data.

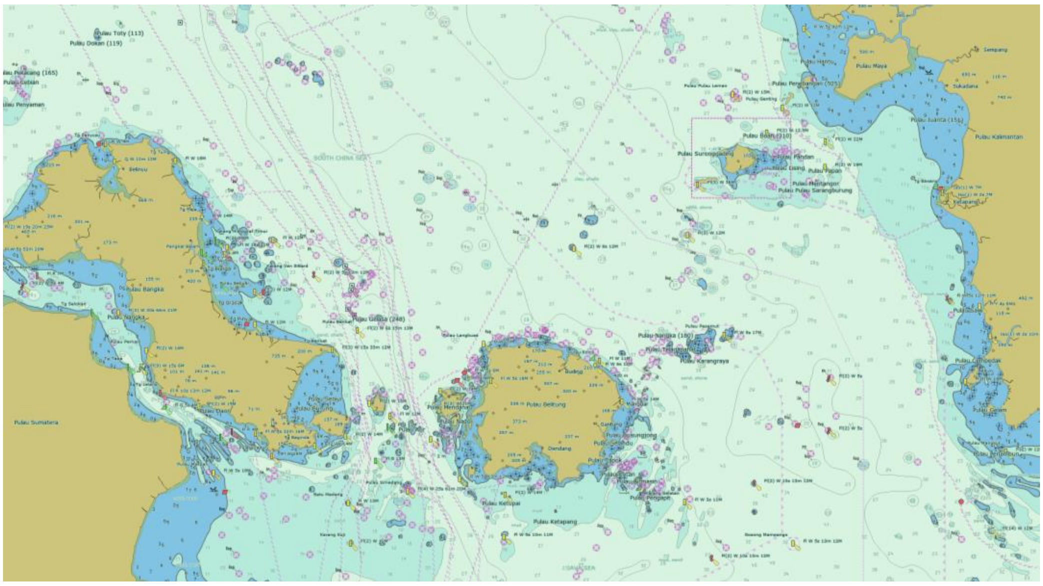


Figure 2: EAHC Small scale cell of SCS

3.3.3 Flexibility

The key to success is likely to be a scheme with as much inbuilt flexibility as possible. All the RHC core members are well versed in the terminology and nuances of gridded production but all are at different stages of development, Norway for example has always gridded all of its coverage while US and Canada are just starting to shift to such production methods.

The following sections propose a number of options along with some recommendations for moving such a proposal forward. It is likely that a number of iterations, taking into account individual requirements and adapting a proposal, are likely to take place and the eventual proposal is likely to be a superset of differing requirements gained through discussion and negotiation.

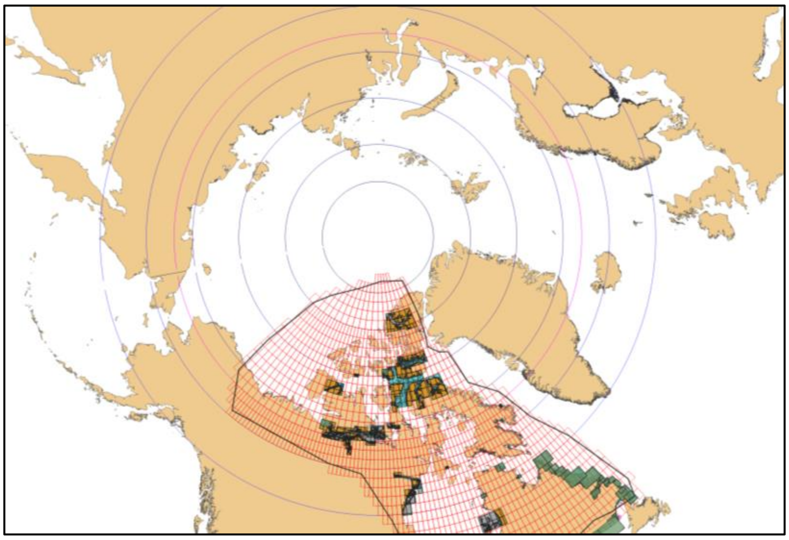


Figure 3: Current proposal - the starting point!

3.4 S-100 production in the region.

The Arctic is largely a blank canvas for the production of S-100 marine geospatial data but presents an enormous opportunity for collaboration, production and joint co-production. The impetus given by the IHO to a broad range of data products offers the regional members a comprehensive framework against which harmonised, well-defined and consistent data can be made.

The production of ENC charts for the region is an obvious use case for any regional proposal and the adoption of S-101 has offered many member states the option of gridding existing coverage or extending existing grids to a broadening set of product specifications.

Recently the IHO S-100WG has begun to define how primary ECDIS navigation will adapt to the emerging IHO S-101 (ready for inclusion in the formal IMO process against the ECDIS performance standard). Additionally, many other products such as S-102, S-121 and S-411 are published and ready to enter a production stage.

The next section of this extract proposes options for content and scope of cooperation within the region for gridded data content and this section reviews some of the possibilities for data production which could be approached with a common grid.

An important element to note in the context of S-101 is that existing S-57 coverage may need adaptation – this is a consequence of the likely modifications to the IMO performance standard for ECDIS in terms of its use of dual fuel S-57/S-101. This was discussed recently at the S-100WG meeting and an Annex to this report summarises the outputs of those sessions. This is ongoing, however, and although it will develop in the future the main points regarding coverage and the impacts on data producers are highly relevant to any cooperation involving ENC production.

3.4.1 S-102.

The potential for creating S-102 data in the region against a defined grid is clear. Where such datasets are capable of production through the necessary survey the data can be produced and the grid used as a container for holding the array of bathymetric values. The only issue to be considered is whether the sizes of the grid cells are of an appropriate size to hold the data required. S-102 is distributed as data encapsulated as a number of nodes and S-102 edition 2.0.0 contains sizing calculations to guide producers in their compilation.

> Table F.1 estimates the possible number of records for a given S-102 file. This estimation is based on file size constraints and the estimates described above. Rounded to the nearest hundred, this estimate allows us to state that a file not exceeding 5700x5700 nodes will remain below the 256 MB, and a file not exceeding 600x600 will remain below the 10 MB. Figures F.1 and F.2 depict maximum grid size for 10MB and 256MB.

Figure 4: From IHO S-102 v2.0.0

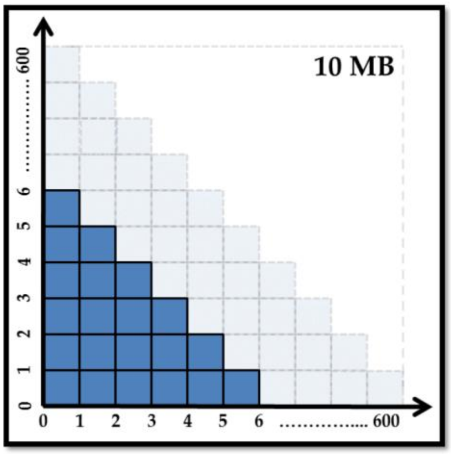


Figure F.1 – Informative grid extents for a 10 MB Uncompressed Dataset

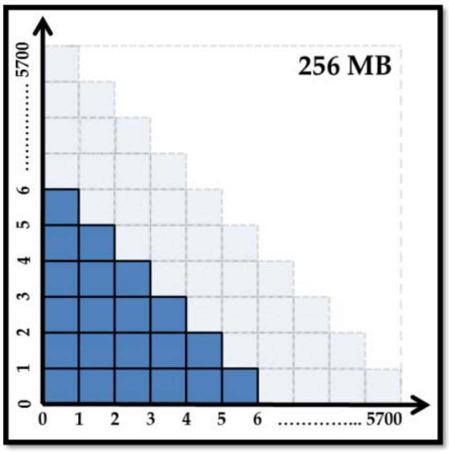


Figure F.2 – Informative grid extents for a 256 MB Uncompressed Dataset

Sizes of the 0.1° resolution cells vary from 5,400m width (just north of the largest scale charts around 80°N) and 11,169m tall to 6,745m wide and 5,400m tall. At these sizes, in order to maintain the 25Mb size limit for S-102 cells the maximum resolution is therefore about 9m or 1m (if the S-102 is cropped to a square extent within the cell) and 10m/100m resolution possible for 256Mb/25Mb file sizes at the 1 subdivision.

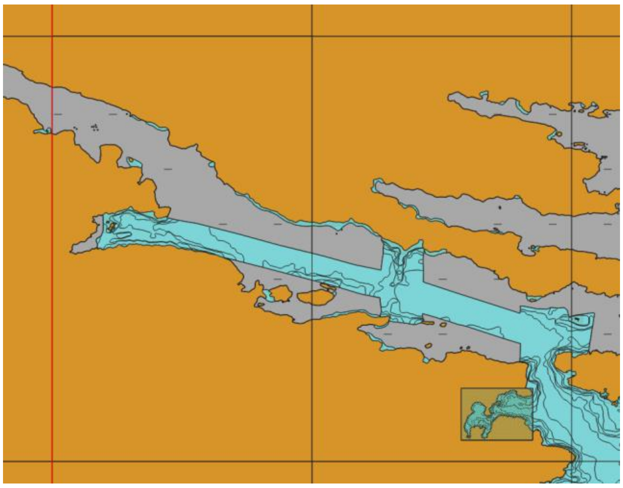


Figure 5: Detail from CA476830

Some areas of production could be clipped to the existing DEPARE coverage within the ENC which would allow for greater resolution within a single grid cell.

The main consideration in this production is really how practical the communications are with vessels planning to use such data and the ease of its use. S-102 potentially provides far greater granularity of planning and tactical maneuvering within restricted waterways but the communications issues in the Arctic are well known. Although recent developments are planned for Arctic coverage by e.g. Inmarsat it is still unlikely such large data payloads will be sent wirelessly to vessels already operating in Arctic waters so it should be assumed that S-102 will be installed locally or via hard media prior to departure on a voyage leg. There are no issues though in the production of S-102 in order to support vessel navigation.

Similarly both S-104 and S-111 data can be produced and the main issues, as with S-102 are the viability/cost of production and its benefit to the user once produced. Plans for ENC production within the Arctic region once the grid is in place would schedule such data collection alongside production of charts to modern standards.

3.4.2 S-411 Ice Information

It is unknown what CHS's plans are for any adoption of Ice information within the region but a mention of it in the context of S-100 product specifications is necessary in such a study. S-411 has been established for many years now under the JCOMM domain.

The product specification, unlike S-102 is vector based and uses a GML encoding. The data produced by BSH (one of the main providers) is small in size (7.5Mb covers the entire region) and is compressible to just under 2Mb.

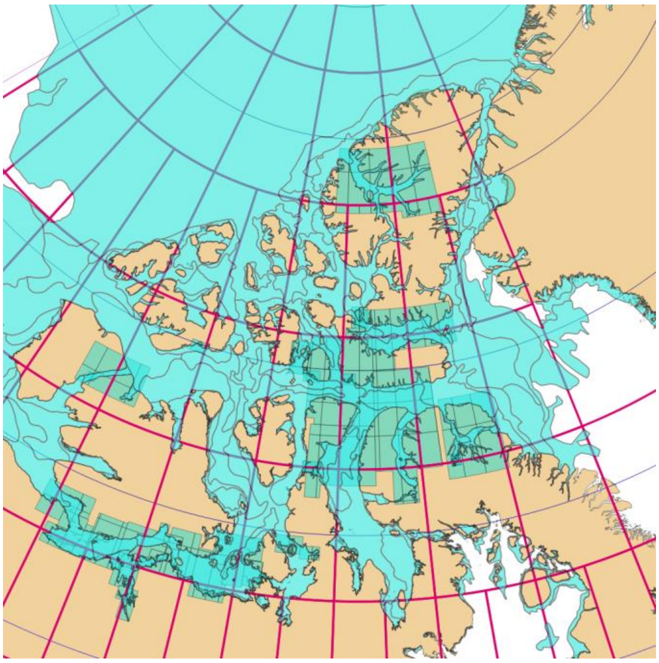


Figure 6: S-411 Arctic coverage extract

The reason this is important in the context of grids is whether a future production of S-411 would also grid such data. It would be possible and, indeed, gridding could be achieved automatically by processing of the GML data. A consideration for future distribution systems would be whether to bundle such data alongside other S-10X products. It is understood that the future CHS production system will grid all data for delivery to end users.

3.4.3 S-121

A special mention could be made within the Arctic context of S-121. This product specification, published in 2019 represents maritime limits and boundaries and has been the subject of the recent OGC MLB project, of which Canada is a major sponsor. Additionally, as noted in earlier sections there are some significant S-121 domain features currently included in CA charts, particularly the EEZ limits and straight baseline claims. The OGC project has explored many aspects of these features, their creation and the legal sources used but for the purposes of this analysis they are considered as important features to be maintained within any gridded rescheming of the area.

In "grid" terms S-121 has few direct references (i.e. it can be either gridded or an overlay to other data depending on the producer's choices) but in terms of the potential for the region it could be a source of cooperation for the states involved.

S-121 contains some elements which would promote regional cooperation for the following reasons

1. States can represent their own limits and boundaries within their own areas
2. A regional grid could contain agreed by treaty limits for e.g EEZ as well as (under the hybrid schema developed under the OGC) extensions based upon those limits for e.g. fishing, hydrocarbons etc. etc.. The grid schema can partition such areas in a neutral fashion.
3. S-121 contains a neutral "collection" field allowing features to be gathered together simply
4. ISO19152 Rights, Responsibilities and Restrictions features, if required by regions could model more complex party relationships as well as treaty sources.

The International centre for Boundaries research and the University of Durham produces an excellent map of the boundaries within the region – agreed under treaty elements of this could be captured from the legal documents and rendered as IHO S-121 data to form a backdrop to data in the region:

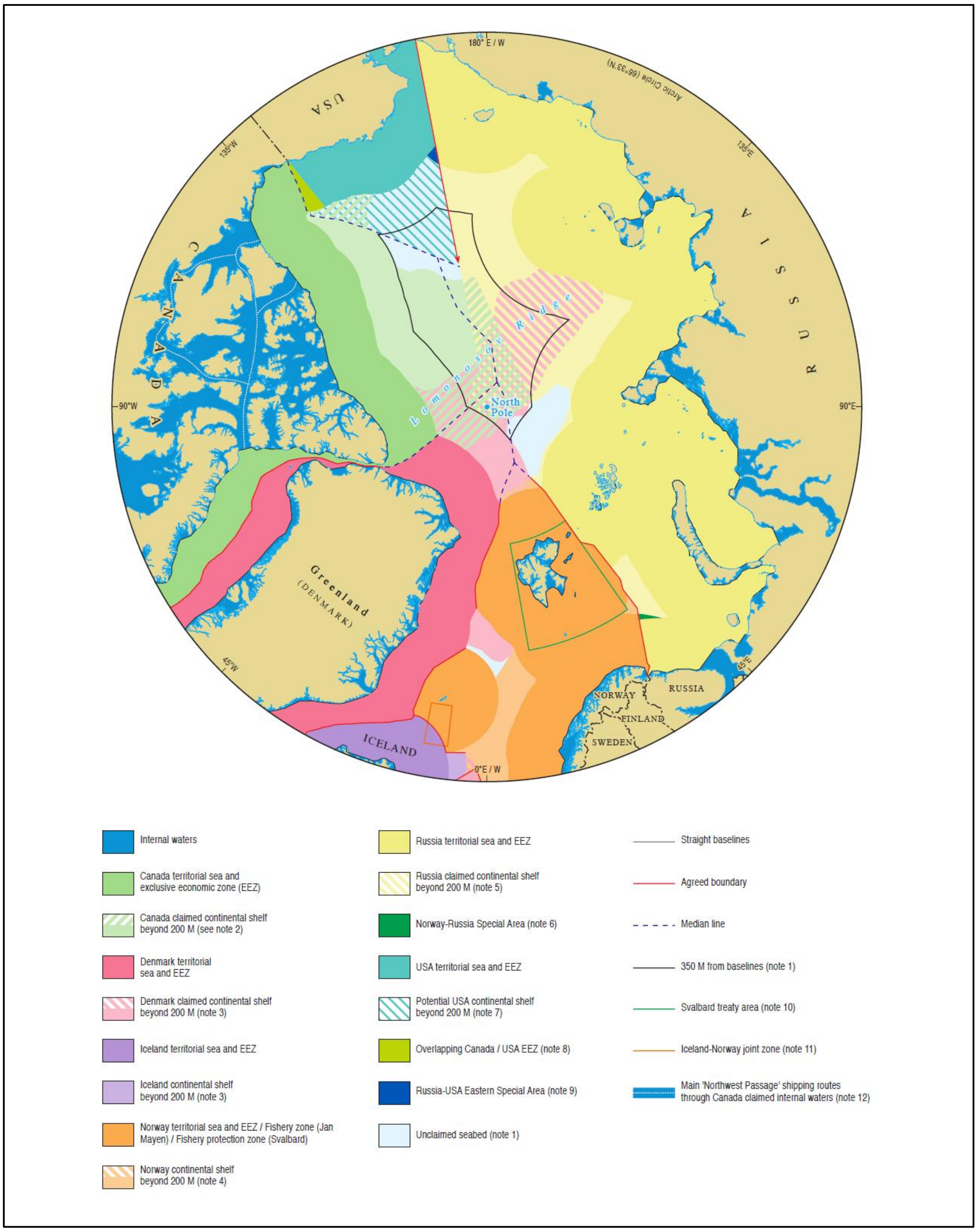


Figure 7: (c) IBRU Centre for Borders Research

4 Other Data providers in the region

In this section we take a comparative look at other data providers in the region and their cartographic/scheming practices in relation to the proposed grid.

The situation with the RHC members and associate in terms of gridded schemes is by no means established or consistent between the individual states. There are three primary outputs from this section of the report.

1. A summary table showing states which grid some or all of their ENCs currently and the observed dimensions of that coverage
2. Detailed data on current ENC extents from each of those countries which may be used as a source for further analysis. This is delivered separately as a spreadsheet.
3. Individual summaries for each state which look at parts of the region at individual scales detail what is known of their scheming practices.

The Arctic Members considered are the following

1. Canada
2. Denmark
3. Norway
4. Russian Federation
5. US

The associate members Iceland, Finland and Italy are also considered.

4.1 Summary table

This table shows what we know or have observed through manual inspection of the coverage for each of the member (and associate member) nations in the Arctic RHC.

In the table ENC usage bands are listed against each member., cell dimensions are noted as "LonxLat", i.e. 4x8 is a cell 4° wide by 8° high.

	1	2	3	4	5	6
Norway	Irregular	2x2 8x2 10x2 (+others)	2x2 2x0.5 4x1	0.125x0.125 0.25x0.25 0.5x0.5	-	-
Denmark (Greenland)	-	-	-	0.5x0.5	-	-
Russian Federation	48.45x14 48.45x15	7x7 9x7 12x5 (+others)				-
US	19.2/38.4	4.8 / 9.6	1.2 / 2.4	2/3°x1/3° [Alaska]	0.075	-
Finland	-	-	-	-	-	-
Iceland	-	Single UB2 –	-	-	-	-

		[-29,-8.5] [62,68]				
Italy	-		-	-	-	-

4.2 Norway

Norway has a well established gridded scheme which has been in place for many years. It is based on the scheme defined under previous editions of S-57, notably version 2 and the approaches defined in earlier DX90 specifications. Norway's gridded scheme is probably one of the oldest amongst ENC producers.

This scheme extends to the Arctic region and covers most cells in the coverage. The gridded scheme does not assign fixed usage bands to grid extents and does not appear to cover all cells within all areas of coverage. Largely Norway's berthing and harbour cells are not all gridded, an example is shown below of Svalbard's largest scale cells:

Figure 8: Norwegian largest scale cells.

By contrast Norwegian small and medium cells are, largely all gridded,

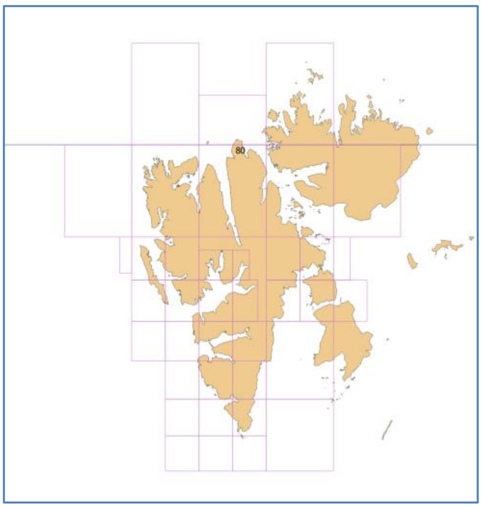


Figure 9: Svalbard Archipelago (NO cells)

The Svalbard example is a good one to follow as it illustrates a key part of the NO grid regime. This shows the Coastal cells and a combination of grid parameters can be seen side by side. The larger extent Coastal cells are 4° by 1° whereas the smaller extents are 2° by 0.5° (they appear square because of the projection in the rendered image).

NO coverage of coastal and general cells are, sometimes coincident at lower latitudes but within the Arctic region there are few Coastal cells outside the gridded ones in Svalbard. General usage cells north of 68° are generally 8° by 2° with a small number of exceptions.

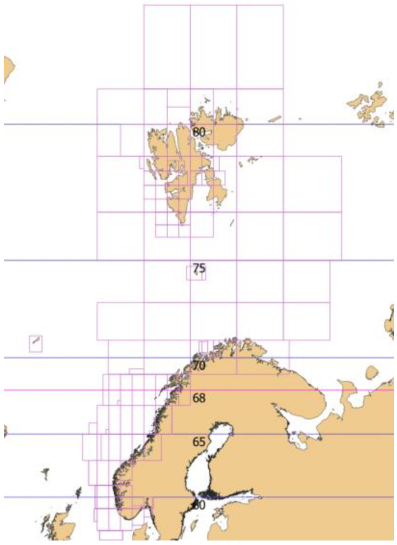


Figure 10: General and Coastal cells (NO)

Larger scale cells for NO coverage are a mixture of ungridded (i.e. based on a particular centre point) and gridded. There is no largest scale coverage in Svalbard or further north but the lower latitudes suggest a preference for 0.25° squares or multiples. Harbour cells in these lower latitudes are a mixture of 0.25° by ° and 0.125° by 0.25° or similar.

4.3 Denmark

Danish interests in the Arctic region are centred around Greenland. Danish cahrting of Greenland is long standing and Greenland also have a public documented grid strategy which is being implemented currently.

Analysis/Discussion

Grid definition

- The grid is based on a latitude-longitude coordinate system.
- The outermost (coarsest) grid-net (so far) has cell size 8° x 8°.
- The South-West corner of the gridded area is 56°N, 76°W, to fit Greenland and surrounding waters in as few 8° x 8° cells as possible.
- This grid will be subdivided in a finer grid, by dividing each cell in 2x2 sub-cells. This process continues, generating still finer grids, always dividing cells in 2x2 sub-cells.
- The finest grid (so far) is 15' x 15' (i.e. ¼ degree on each side).

A specific cell size is not associated with a specific scale or scale-band. An ENC at 1:90,000 could typically be a 1° x 1° cell, but may just as well be a 2° x 2° or ½° x ½° cell, depending on information density in the relevant area. Similar a 1° x 1° cell may likely be in scale 1:90,000, but can legally be at scale 1:45,000, 1:180,000 or other scale.

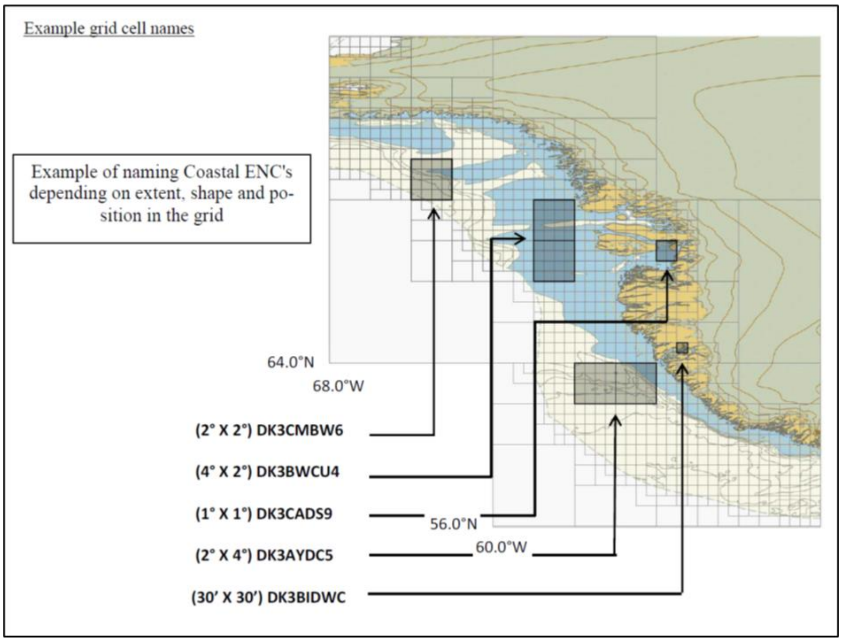


Figure 11: DK (Greenland) grid scheming

This grid scheming is, like Norway (and others) not specific about which grid subdivision maps to particular usage bands and so is flexible in the mapping of ENCs to extents. The other interesting aspect to note is that the scheme not only allows aggregation of grid cells together but assigns codes to particular "shapes" of cells, i.e.

Shape indicator
Each size/shape combination is described by a single number or letter.

LAT \ LON	8°	4°	2°	1°	30′	15′
8°	0	1				
4°	2	3	4			
2°		5	6	7		
1°			8	9	A	
30′				B	C	D
15′					E	F

- 1° x 1° cell is a shape '9'
- 1° x 2° (horizontal) cell is a shape '8'
- 2° x 1° (vertical) cell is a shape '7'.

In this table the grid specification defines a number of rectilinear cell sizes each defined with its own code (in the naming scheme). The paper also alludes to "other", possibly irregular shapes which can have their own codes such as L-shaped cells. These are seen in other states, most notably Korea:

Figure 12: Example irregular grid cells from Korea

At the current time, though, only rectilinear cells are implemented in the Greenland scheme predominantly 0.5°.

The scheme does not prohibit overlaps between usage bands, so an Approach cell could be coincident with two General cells at their boundaries. It does, however, have a fixed resolution of its subdivisions. It has a smallest resolution of 8°, progressively subdividing by a factor of x2 leading to cell dimensions of 8°, 4°, 2°, 1°, $\frac{1}{2}$° and $\frac{1}{4}$°. In this respect it is similar to the US system of scale subdivision (done in support of better compatibility with web mapping services).

Whether this will eventually result in wholesale gridding in the rest of the DK coverage remains to be seen but they are extremely supportive of the S-100 framework and it seems likely this will be the case longer term.

4.4 Russian Federation

The Russian Federation cells show a variety of approaches. The RU coverage is, of course, extensive.

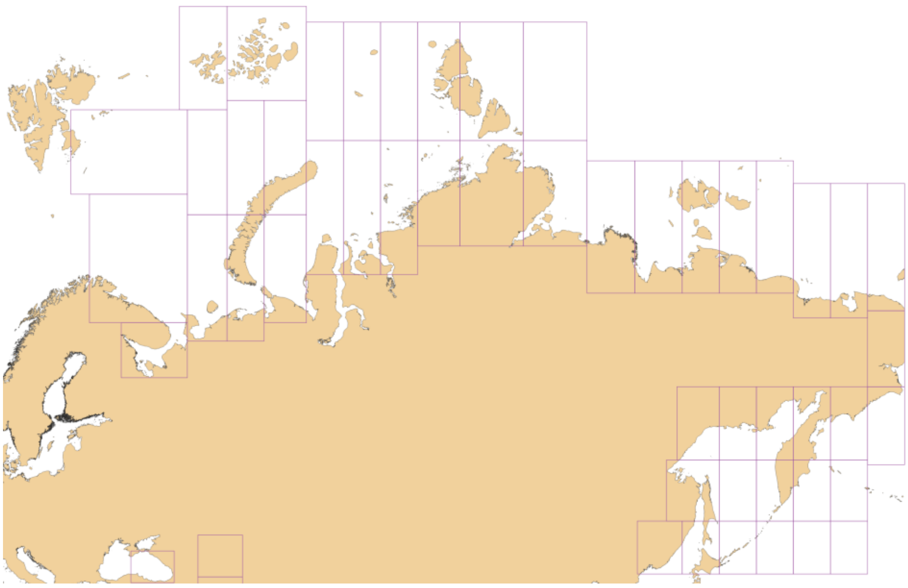


Figure 13: Russian Federation General usage band ENCs

The only usage band ENCs to show any evidence of gridding are the General ones. These cells have a variety of sizes but are, predominantly 7°x7°. There is also evidence of broadening of cells in the northern part of the coverage with widths of 8°, 9°, 12° and 22° . The gridding is not completely consistent but does show a general approach of aligning cells within the usage band. This is not replicated or subdivided at other usages though.

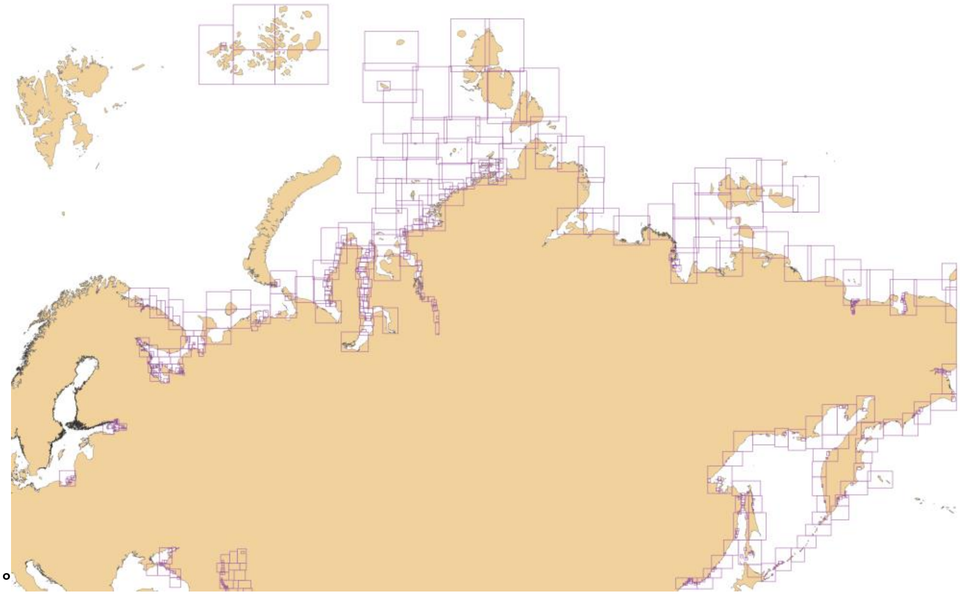


Figure 14: RU coverage across entire region (Coastal, Approach and Harbour)

The rest of the RU coverage is almost all irregular and ungridded. Two possible exceptions are the cells issued for Franz Josef Land and Eastern Ukraine in 2017 and 2019 respectively whose extents have a grid-like appearance. Whether these cells show a more formalised approach to gridding or not remains to be seen.

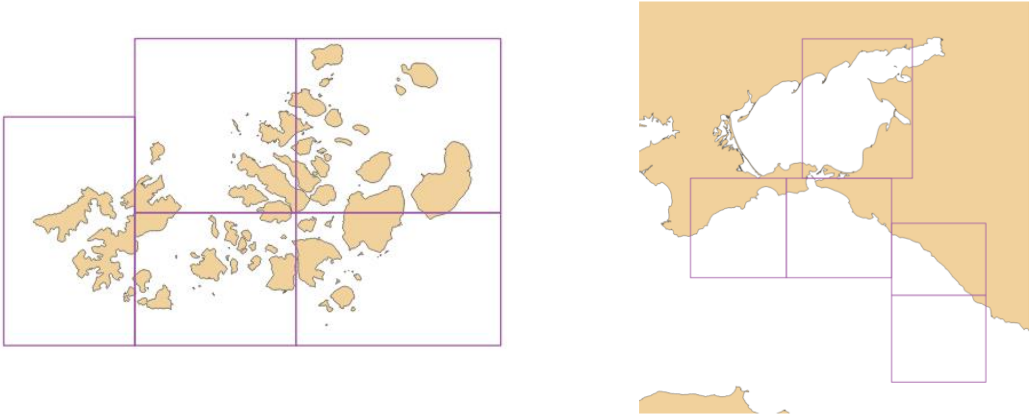
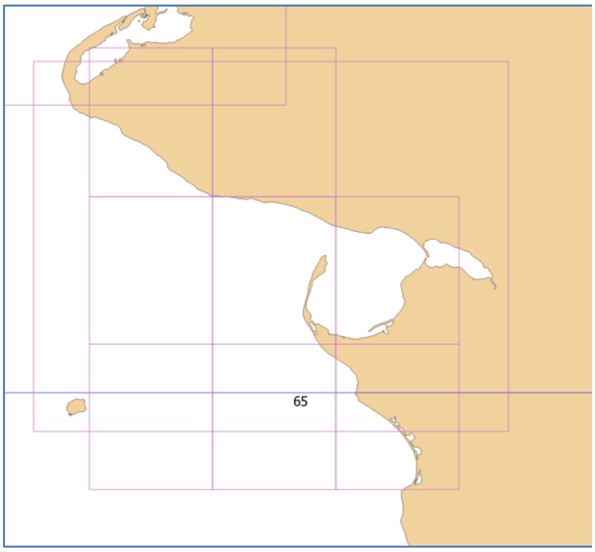


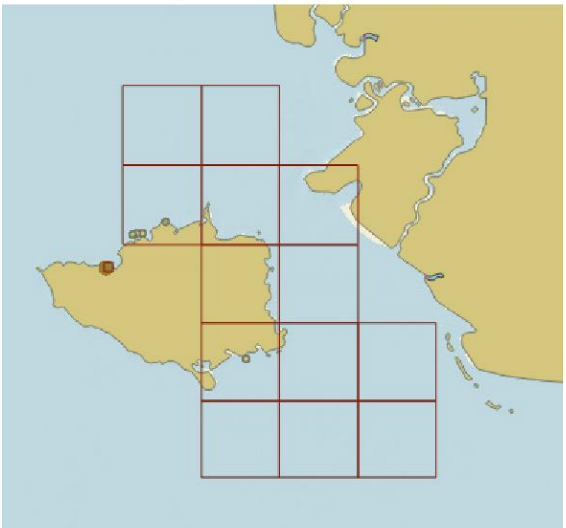
Figure 15: Coastal coverage in Franz Josef Land and Eastern Ukraine

4.5 United States

The US's grid scheming stems from a commitment in the National Charting Plan committing NOAA to a rescheme based on a grid (the primary goal being rationalised charting together with support from multiple products on a single grid.

An example of US gridded Approach cells are shown below:

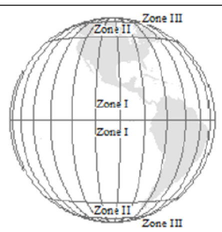




The scheme is based on the following diagrams, taken from NOAA's public presentations supporting the national charting plan. This broadens the width of cells as the latitude increases, as is evidenced in the Alaskan cells (2/3° x 1/3°)

Table B.2 ENC Cell width dimension zones

Zone	Latitude
III	64°N - 80°N
II	48°N - 64°N
I	0° - 48°N
	Equator
	0° - 48°S
II	48°S - 64°S
III	64°S - 80°S



Scale band	Standard Scale (rounded)	Width	Height
Band 1	1:5,120,000	38.4	38.4
	1:2,560,000	19.2	19.2
Band 2	1:1,280,000	9.6	9.6
	1:640,000	4.8	4.8
Band 3	1:320,000	2.4	2.4
	1:160,000	1.2	1.2
Band 4	1:80,000	0.6	0.6
	1:40,000	0.3	0.3
Band 5	1:20,000	0.15	0.15
	1:10,000	0.075	0.075

The US grid is unusual in that a rigid pattern of dimensions is adhered to with the compilation scales capped directly to grid extents. This is (partly) to support better performance of charts in web-based applications where zoom levels are defined against a logarithmic scale. This also fits approximately existing guidelines on compilation scales in usage bands but leads to fractional (degree) dimensions throughout the scales.

The grid also is not defined in terms of origin and may not be fixed in origin between spatially disjoint areas. Indeed, one of the images from the national charting plan shows a potential scheming for new ENCs:

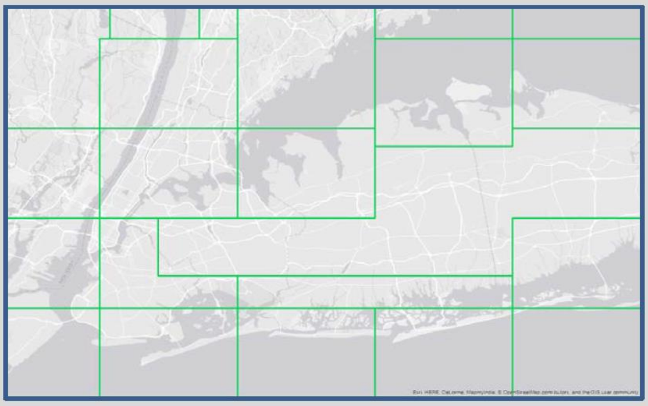


Figure 17 – Possible New ENC Scheme for Harbor Usage-band in Western Long Island

In the image although "gridded" in terms of tessellated rectangular extents (mainly) the coverage is not regular as some of the parallels of the cells are not aligned between neighbouring cells. This implies a looser definition of "grid" but requires some verification to be completely authoritative. Certainly the evidence from the AK cells illustrated shows a fixed grid (although the AK region is spatially disjoint from much of the rest of the US so a fixed origin can not be implied.

The important fact of the US grid (as observed in the Alaska cells), though is the doubling of the width of the cells in the high latitudes and the definition of cell extents along with their fixed compilation scale mappings.

5 Rectilinear Proposal(s)

In this section we propose a number of options for grids which could be used throughout the region. These are all rectilinear, so they are composed of a sequence of tiled "rectangles" formed from parallels and meridians as per all the grids considered in this study and proposed under the SOW. The key advantage of proposing a rectilinear grid is its familiarity with the RHC members – in some sense most have already "bought into the concept" of grids and so a proposal using such language already passes many criteria for acceptance.

As observed elsewhere in this report the broad requirements for any rectilinear grid in the region are:

1. Must be simple dimensions, whole number degrees or simple decimal or fractions. Reflects current practice of NO, DK and CA. Also RU charts in the region are whole number degrees
2. Must cover entire region from -180 to +180 Longitude
3. Should be reasonably similar in coverage/extent to existing CA grid
4. Subdivisions should ideally be simple fractions.
5. The highest resolution is 0.1° (CA) or 0.125° (NO)
6. Area and skew is kept under control by progressively doubling the breadth of cells at the same subdivision (CA, US, NO)
7. Politically neutral. Needs have a neutral origin (the dateline is probably most appropriate)
8. Subdivide around the pole – ENCs currently cannot include the pole itself.

As noted in the previous section when considering other states' grids (or lack of grids) within the region the various aspects of the grid to be specified are:

1. A single origin
2. A fixed set of dimensions for a number of different subdivisions
3. Common cell boundaries between resolutions
4. How the grid maps the Area of Interest without gaps
5. A concrete mapping of compilation scales to grid subdivisions
6. Charts defined within single grid cells only

And it was noted that some states define all of these elements whilst others do not. In order to propose a grid for the region (however we define the "region") these elements will be addressed in some way. It is recommended that any regional proposal is flexible, however, so some may be relaxed or optional for participants.

5.1.1 Choice of origin

Likely to be international dateline and pole in order to fit with existing navigation equipment. The dateline is also politically neutral although many states use meridians and parallels for chart boundaries and there are some UNCLOS boundaries founded on historical meridians/parallels, most notably of course US and Canada.

5.1.2 Choice of dimensions and subdivisions.

By inspection of the summary table of the other states within the region and the existing proposed CA grid a grid which can be subdivided in factors of 2 seems to make sense. This is a driver for both the US and DK (Greenland) and the current CA grid contains a x2 subdivision between overview and transit usages already.

The main difficulty with factors of two is that the regional grid needs to cover the entire region, from -180 to +180 Longitude. Individual countries only gridding for their own area of interest can create grids using the following integer multiples of degrees:

$$8°$$
$$4°$$
$$2°$$
$$1°$$
$$\frac{1}{2}°$$
$$\frac{1}{4}°$$

Figure 16: Exponential grid subdivisions

However, in order to cover 360° of longitude the choices are somewhat limited. The additional requirement to broaden cells to account for the narrowing towards the pole means that, to avoid cells which are fractional at the smallest scales a decomposition of 360° needs to be considered for the breadth of cells as well as their dimensions at the different resolutions[1].

The 4° height of cells within the CA proposal works well and is a good fit at the smallest scales but replacing the width with 6° a set of cells which can cover the whole region can be defined which additionally can be doubled in width as they approach the pole, resulting in (broadly) rectangular cells.

Along these lines then, it is proposed to use multiples of 6° in the longitude measurements but maintain with a reasonably constant 4° as the height of cells. This enables whole number of degrees for the cell widths and covers the entire region 0-360°. This gives cells of 6°x4°, 12°x4° and 24°x4°. Any subdivision into say, 4 or 8 results in non-whole numbers of degrees at the smallest scale (e.g. 22.5° width cells) which then becomes even more difficult to subdivide for the higher resolutions.

It is also proposed that, at the highest latitudes, extending up to the actual pole, the region is divided into 5 segments of 72°x 4°[2] - this effectively covers the pole with a small number of polar cells each of which could be filled with subdivisions from any of the producer nations or a combination of producers. The existing proposed scheme ends at 88° N thus leaving a 2° region of latitude unfilled. For completeness of any proposal it should cover the whole region at least one resolution. The extension of the grid scheme to the pole inevitably results in some areas where the meridians are broken, short of the polar region itself.

An illustration of the proposed grid is shown in the following diagram along with the ENC coverage from the RHC core members and associate members and the CA ENC cells within the study for context. This could be clipped to any latitude or other defining area for the Arctic.

[1] The reason why 8° works well is it can be decomposed into whole number of degree cells at higher resolutions but also broadened as the cells progress further north.

[2] From a “marketing” standpoint this nicely reflects the existence of the 5 core members of the RHC!

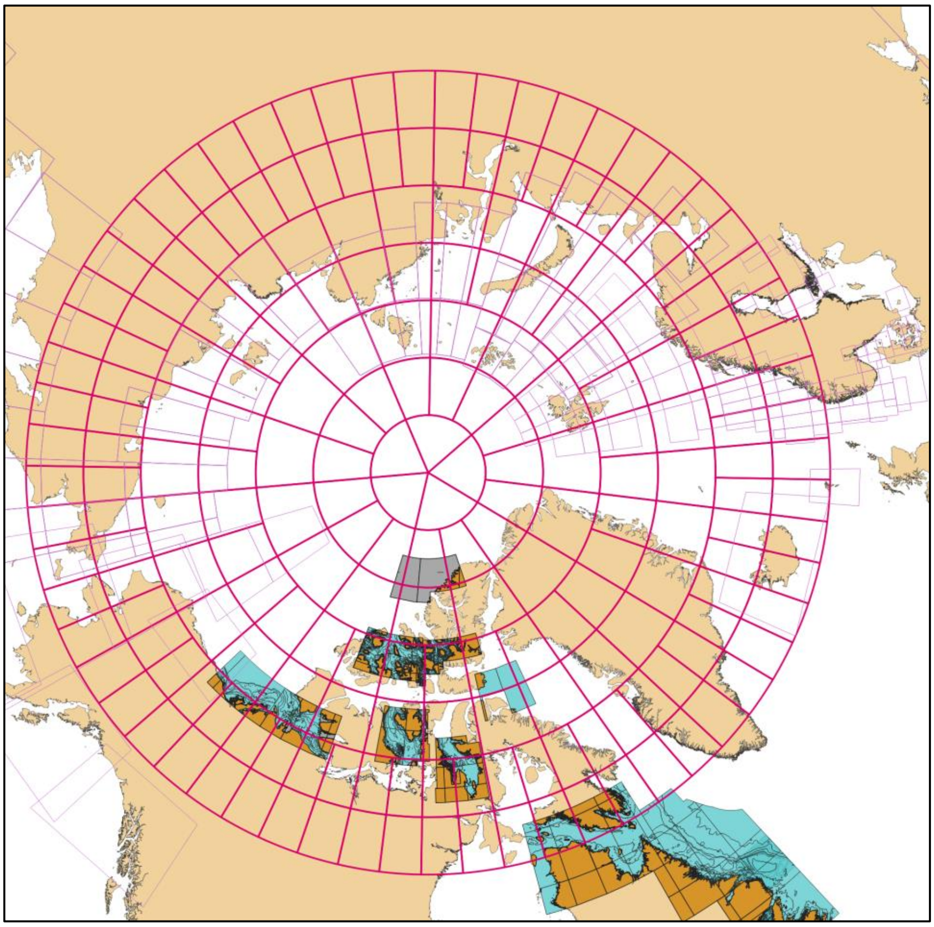


Figure: Proposal 1

It is then proposed to continue the existing proposal for single degree cells within the smaller scales for the first level of subdivision, scaled appropriately according to latitude. The Polar region is split into two rows of 1x24° with the top 2° at the pole a single cell. This preserves a broadly rectangular shape for the far northern cells and reduces the amount of skew in the cells.

This subdivision into 1° cells would then provide for a further subdivision into 0.1° cells, again, scaled according to latitude. The advantage of 0.1° cells at the highest resolution is their ability to be aggregated into 0.5° cells which many providers have at intermediate scales. Many providers also have 0.25° at scales but in order to retain whole numbers within the subdivisions the 0.1° is proposed.

At the actual poles the highest resolution would be ungridded. It makes little sense to establish regular "rectangles" based on degree measurements at this latitude. Any regular gridded requires increasing amounts of compensation for the increasing latitude and is unlikely to be meaningful for many purposes.

It is also worth considering whether the grid should allow the third subdivision, the highest resolution to be ungridded. Currently many other gridded countries do not grid at the largest scales, NO being the singular example within the region. This practice combines the efficiency of a gridded approach at the small scales with the geographic flexibility required for Harbour and Berthing cells (without them being split along gridlines). This approach would have some merit with the RHC members who do not wish to necessarily grid all their products at all scales.

An illustration of the next subdivision is shown in the following diagram:

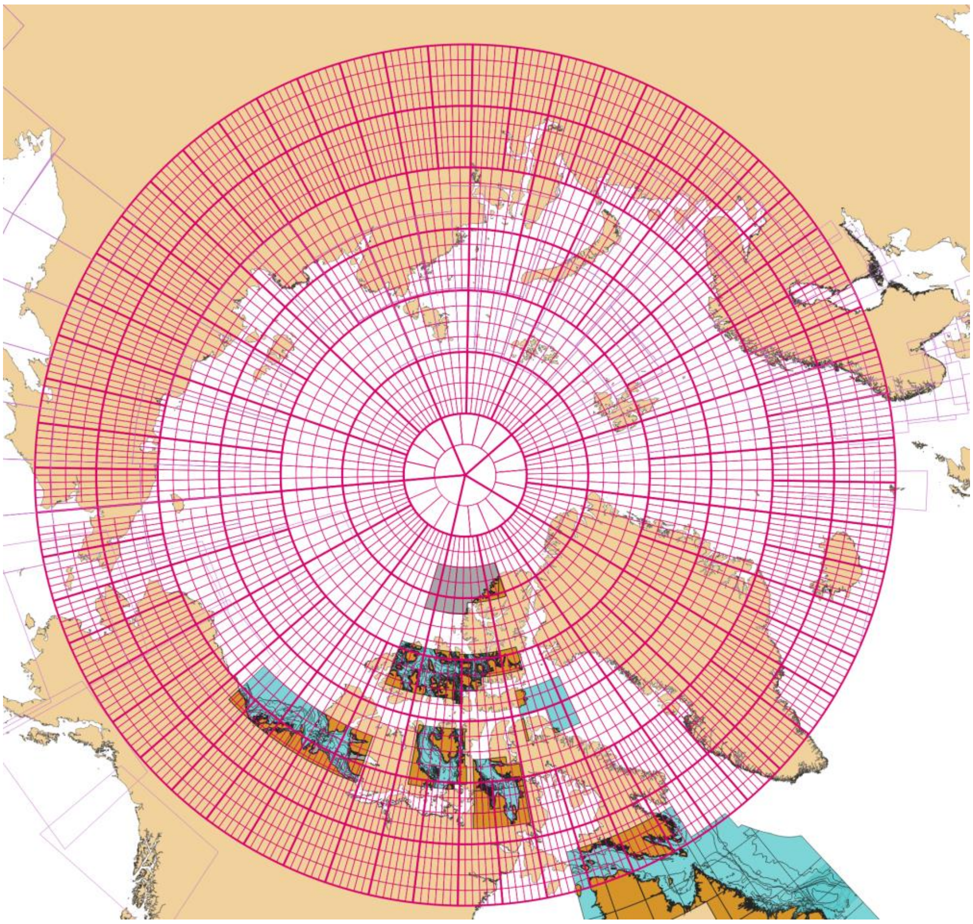


Figure 17: First subdivision of the regional grid

5.1.3 Compilation Scales.

In order to accommodate the large disparity in compilation scales and cell extents between the various states within the region it would be worthwhile not explicitly mapping each grid subdivision to an individual usage band (either for S-57 or S-101 usage). This would allow states to maintain their current extents (broadly) and to assess feature densities within their own coverage.

The grid would, effectively be a “usage band 0” where the extents are defined and the data producer is to assign an individual scale band (S-101) or usage band and compilation scale (S-57) to the cell when it is created. This allows for a great deal of flexibility in assigning individual cells to subdivisions of the grid.

This practice is in place within Norway and is seen in the Greenland specification as well. Management of overlaps across boundaries and regions would be done between members. This arrangement would also facilitate discussions on scale banding to harmonise ECDIS behaviour across boundaries as well. Joint production of data could be a useful exercise in this context.

5.1.4 Aggregation

This principle of the grid could also be left flexible for implementing data producers. Although the current CA scheme does not currently allow for aggregation between adjacent grid cells this is an intrinsic part of the published Greenland scheme.

It helps to reduce the number of cells required for maintenance and, although it introduces a manual "scheming" process this is a small overhead to pay. In particular, this would allow e.g. NO and DK to implement 0.5° cells at the higher resolutions in line with their current scheming.

5.1.5 Summary - Dimensions

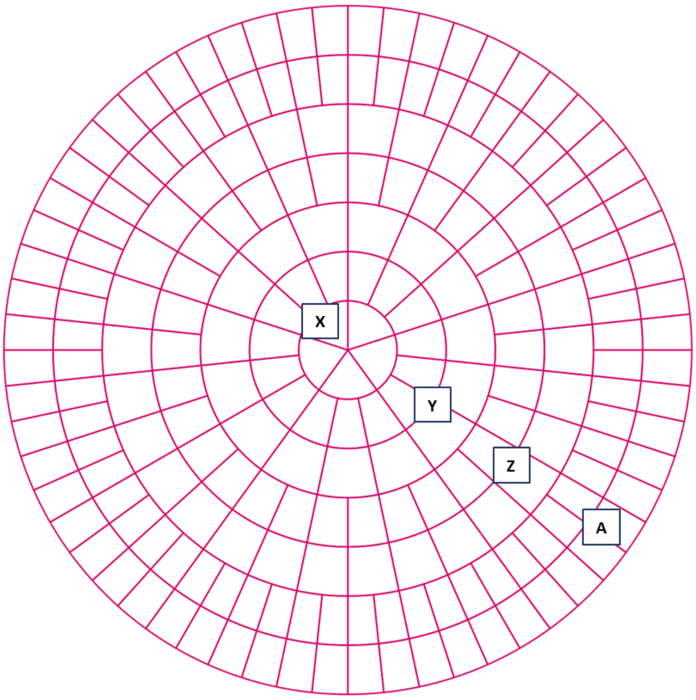


Table 1:Grid Zones

Zone	Latitude °	Width	Height
X	86°	72°	4°
Y	78-86	24°	4°
Z	70°	12°	4°
A	62°	6°	4°

Table 2: Rectilinear grid proposal v1.0

Subdivision 1 splits Zone X by adding two rows of 18°x1°, Zone A into 1° cells and then scaling the breadth accordingly, so Zone Z = 2°x1°, Zone Y = 4°x1°.

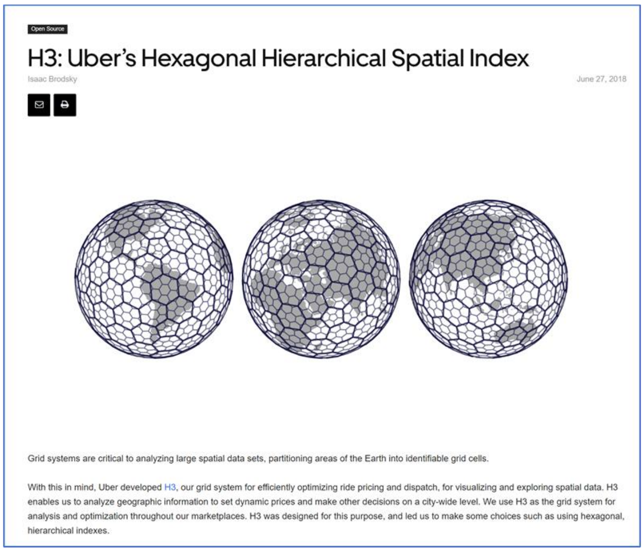
Subdivision 2 splits these cells into 1/10th of their dimensions

6 Non-Rectilinear

The other option for a regional grid, and one which is slightly more radical, would be a grid based partly on non-rectilinear cells. A hybrid rectilinear / non-rectilinear grid is one where some part of the grid definition is based on shapes which are non-rectangular (insofar as a mixture of parallels and meridians is, in any way, a “rectangle”). Such grids are common in other domains and have been used for many years for various purposes since their invention in the mid 70s following pioneering work by Buckminster Fuller. A more general class of global grids called Discrete Global Grid Systems (DGGS) is used to describe many types of schemes where the globe (or part of it) is tiled with regular shapes (not just rectangles but triangles and hexagons).

The interest in such schemes has led to an OGC domain working group and an OGC abstract specification defining terms for them and many implementations globally.

More recently such grids have been popularised by Uber, who open sourced their hexagonal grid of the world, used for processing and calculating approximate distances between customers and vehicles within a certain region.


Open Source

H3: Uber’s Hexagonal Hierarchical Spatial Index

Isaac Brodsky

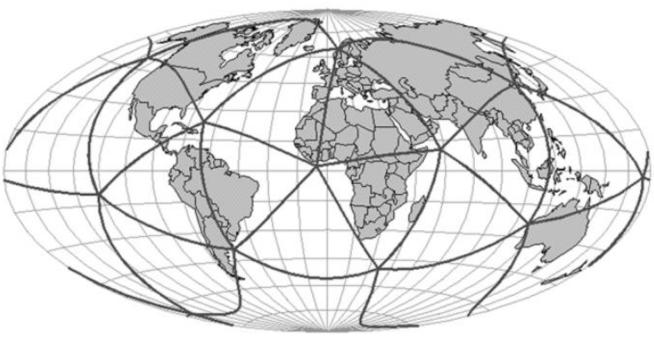
June 27, 2018

Grid systems are critical to analyzing large spatial data sets, partitioning areas of the Earth into identifiable grid cells.

With this in mind, Uber developed H3, our grid system for efficiently optimizing ride pricing and dispatch, for visualizing and exploring spatial data. H3 enables us to analyze geographic information to set dynamic prices and make other decisions on a city-wide level. We use H3 as the grid system for analysis and optimization throughout our marketplaces. H3 was designed for this purpose, and led us to make some choices such as using hexagonal, hierarchical indexes.

Another useful grid of note is the US EPA’s Superfund_500m grid, commissioned by the US EPA in 2003 for the development of the Superfund Emergency Response Atlas.

Such a grid is based on an icosahedral projection which divides the earth’s surface into a set of triangles, uniquely defined by a single point and azimuth.



The triangles are then subdivided into a series of hexagons by trisecting each side and joining the six vertices together. This process is repeated to form multiple layers of hexagons at different resolutions.

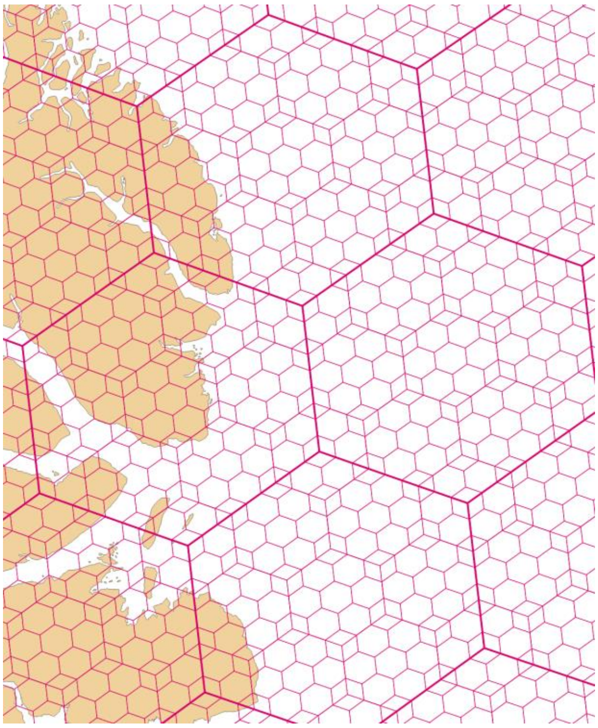


Figure 18: An example of a DGGS showing three resolutions

A great deal of information on the DGGS is contained at the original website:

http://cs.sou.edu/~sahrk/dgg/pubs/gdggs03.pdf

as well as https://www.discreteglobalgrids.org/

which includes many research papers and documented implementations.

Although DGGS has been around for many years and has been raised at IHO level in the past, no concrete implementations have ever been done and its use for holding chart coverage has remained a theoretical possibility.

The key advantage for the Arctic region is that such a division of the region tessellates the area equally, that is, each component hexagon at a specific resolution has the same surface area and is also not skewed as rectangles become as they approach the pole – indeed the hexagon is the most rectilinear-like shape possible to tile the plane on a spherical body. This equal-area property and minimisation of the skew make such a partitioning of the space suitable for a broad range of MSDI applications in addition to the potential for carrying and maintaining chart coverage at multiple resolutions.

The equal area property of the DGGS is used most often to produce geo-statistics and heatmaps where it is required to count the number of datapoints within a particular area. The much increased volume of scientific research in the Arctic would benefit from such a standardised system across the region rather than trying to express data whose positions are measured using degrees, minutes and seconds. Such systems are frequently used to represent coordinate positions at resolutions up to one metre.

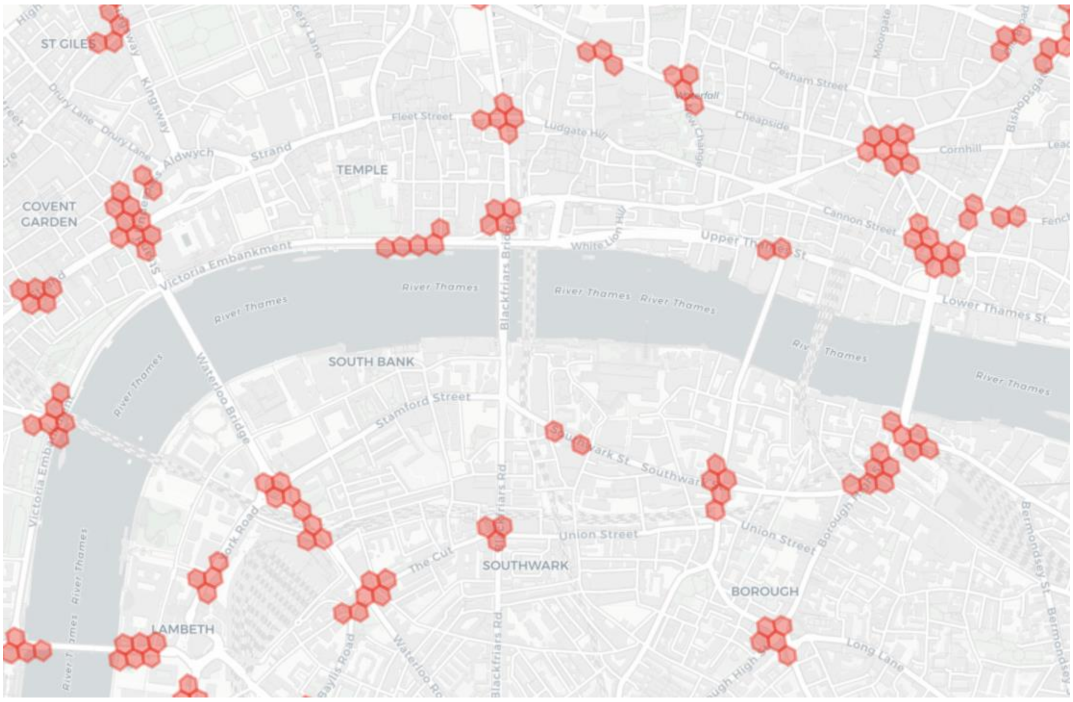


Figure 19: Using Uber's H3 system to cluster data

By way of example a dataset has been constructed and is illustrated in the following diagram.

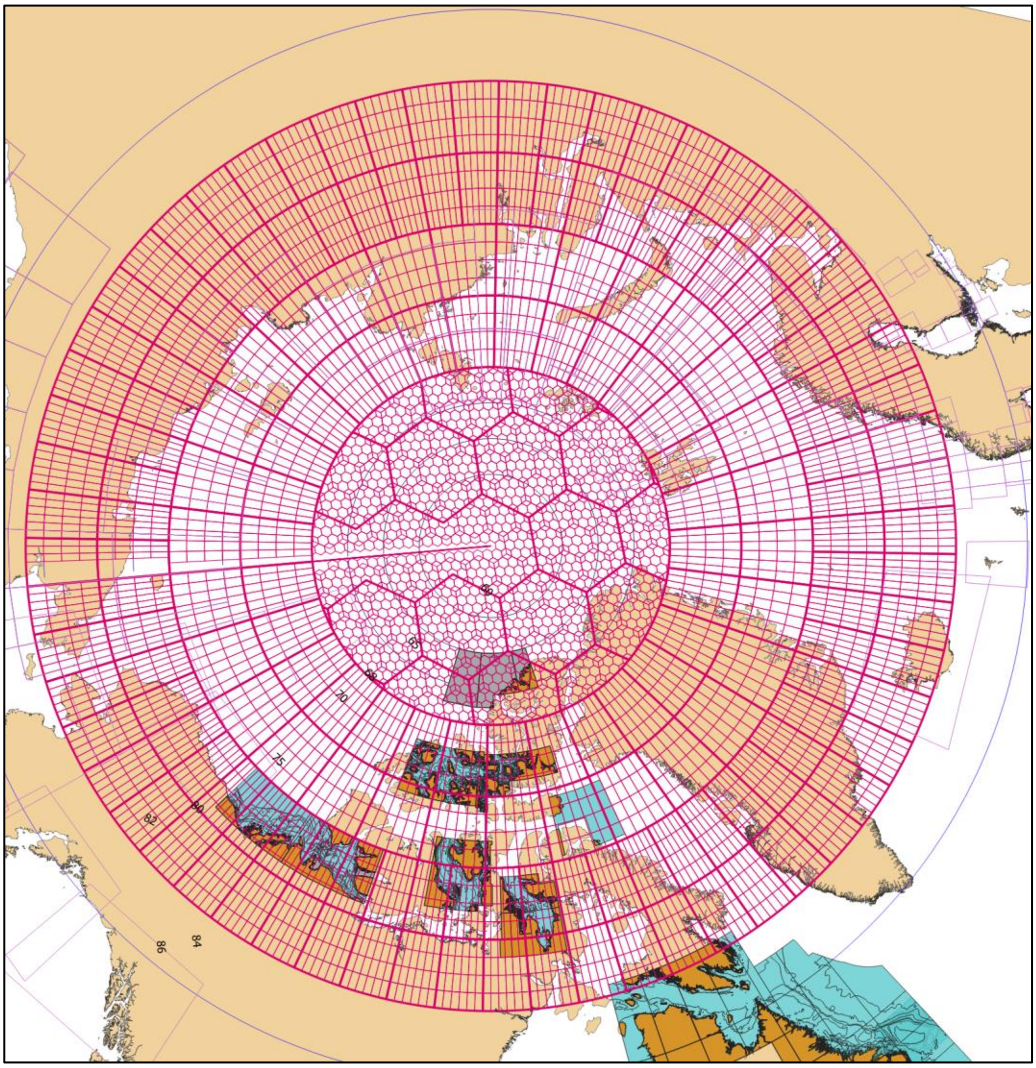


Figure 20: Proposed hybrid DGGS / Rectilinear proposal for the Arctic region.

The illustration shows a combination of a hexagonal DGGS based on the ISEA3H algorithm, with a fixed point on the equator with azimuth 90° - this leads to a cell covering the pole itself (The in. The three resolutions shown approximate the areas of the Overview, Transit and Port cells in the rectilinear proposals.

The following image shows a close up of the hexagonal region of the proposal:

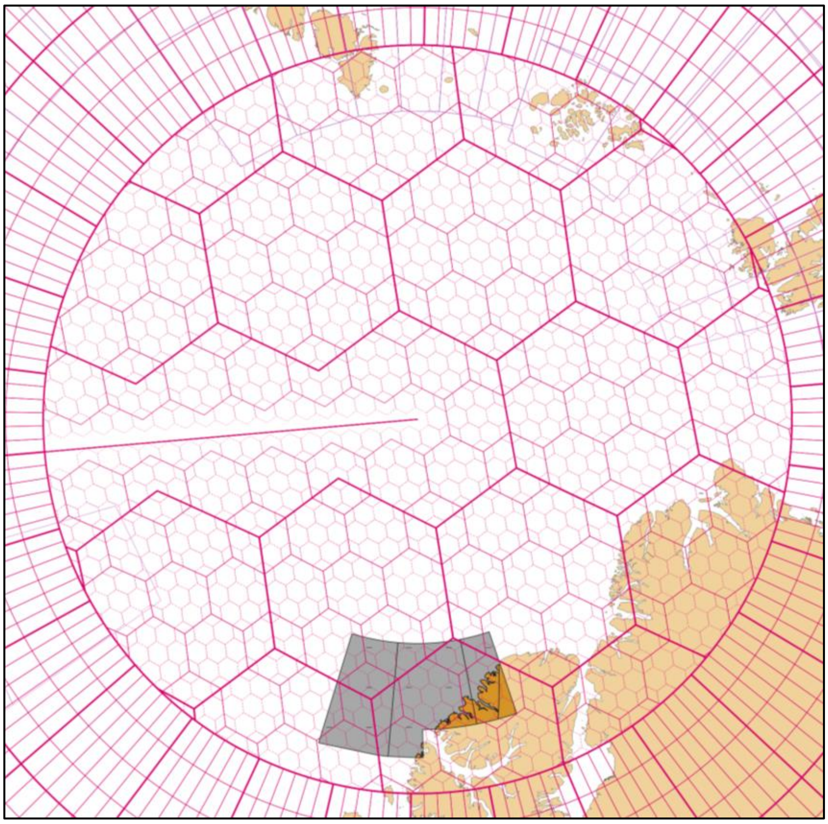


Figure 21: Polar region of non-rectilinear proposal

Some points to note are:

a. The region is clipped around the dateline (and pole). In practice this clipping can be much tighter to adhere to existing ENC standards and provide all-over coverage
b. The limiting latitude is clipped against the rectangular cells comprising the southern part of the scheme. This clipping could be reversed – i.e. the rectangles could be clipped to the hexagons. The interface does represent an area with many slivers and small cells but this could be mitigated by aggregating neighbouring cells in the join.
c. There are a number of options for resolution sizes – these are resolutions 4,6 and 8 of the ISEA3H grid – there are a number of possibilities for different types of grid and other resolutions. The extents are not arbitrary though – the Superfund_500m grid was defined with some geometric compromises in order to fit a desired resolution.

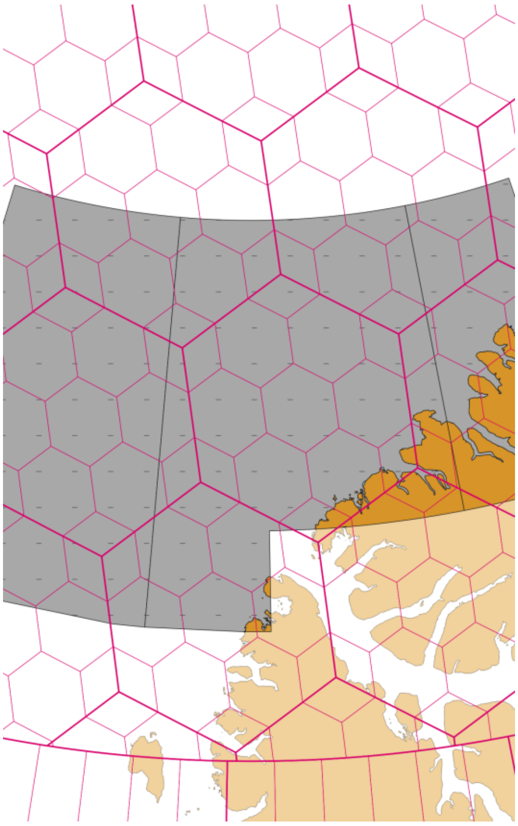


Figure 22: Two resolutions over CA Chart

The main benefits of the DGGS proposal is for the area of the high North. The proposal limits that area to north of 80° but this could be modified. Additionally the area to the South of 80° is composed of rectangular cells to allow for more traditional gridding where many charts currently exist. The Area North of 80° has few charts within it currently and this proposal would create a set of unused cells ready to be assigned to usages exactly as rectangular cells would be. In terms of the

6.1 Feasibility

Is such a non-rectilinear proposal feasible. It is possible to create S-57 cells of such shapes using M_COVR,CATCOV=2 to flesh out cells to rectangular extents and automated processes could create such cells from existing ENCs with reasonable ease. S-101 poses no rectangular requirements so it is possible to create such ENC cells in theory. In terms of data management and production processes some adaptation would need to be made to processed and naming schemes but the hexagonal shape is purely a container for the features within it.

It is worth reinforcing that the coverage features in an ENC only represent the “container” that the chart data is contained within. The data within the cell remains unprojected and the user is only aware of the shape of the cells when they consult a catalogue.

Use on vessels remains in whatever projection is used by the end user. It is hoped that such shapes, because they eliminate the “skew” of rectangular cells will actually assist production and lead to greater efficiencies in updating of cells by optimising the cell borders.

In terms of the criteria for any grid set out in the introduction :

1. Must be simple dimensions, whole number degrees or simple decimal or fractions. The DGGS grid is simple with a single dimension at each resolution. These are not whole degrees but the entire structure is abandoning the concept of measuring with degrees which, in the Arctic region, is fatally flawed due to the enormous skew as they approach the pole.
2. Must cover entire region from -180 to +180 Longitude – this is satisfied by the proposal . Clipping around the dateline will need to be achieved as well as at any southern border with rectilinear systems
3. Should be reasonably similar in coverage/extent to existing. The proposal can represent data with similar areas of existing CA grid cells and with three distinct usage bands as per the existing proposal. Additionally, combining it with existing rectilinear structures allows more southern datasets to stay within the existing system
4. Subdivisions should ideally be simple fractions – as stated, the subdivisions are simple divisions of the resolution.
5. Area and skew is kept under control by progressively doubling the breadth of cells at the same subdivision (CA, US, NO) – not required as skew is dealt with by the shape of the cell itself.
6. Politically neutral. Needs have a neutral origin (the dateline is probably most appropriate) – this is strengthened by avoiding potentially contentious meridians and parallels in the system
7. Subdivide around the pole – ENCs currently cannot include the pole itself. This can be achieved by tailoring the cells around the dateline to avoid crossing in line with existing standards. The choice of origin for the system positions the hexagons astride the dateline at each resolution (although a degree of crossing is inevitable)

The only principle of the grid which the DGGS breaks is the common boundaries between resolutions. At each resolution in the DGGS only about 50% of the boundaries are common.

6.2 Proposal to RHC members and Associate members

A DGGS based proposal for the region has the advantage of being equally new for all participants and, as previously noted, completely politically neutral. The advantages of such a proposal for the broader geospatial community would be the ability to increase the number of subdivisions to much finer levels to serve as a backdrop for other types of data.

The specification of the DGGS within the region could be useful for IHO members to enhance MSDI provision and help interoperability between the scientific and hydrographic communities. DGGS is well established in the scientific and also the OGC community and such a development would provide an alternative to the use of degrees as a metric for measurement – in the polar regions the use of degrees has long been a source of difficulty due to the extreme skew between N/S and E/W metrics. Although DGGS used in this context only solves part of the problem – mapping features to coverage, it would be a significant step.

7 Way Forward.

It is suggested that the proposals here suggest several different potential ways forward. The overall questions of scope (both in terms of geographic coverage and content) should be approached first and use cases established between members. Some prototyping could look at potential data production scenarios and resourcing implications. A match with existing grids could be done to see whether schemes are compatible and how the elective "Scale Band 0" could be used to adapt to existing member state needs. Above all, an open discussion on the merits, resources and benefits/impacts of adoption of the joint Arctic regional grid scheme should be undertaken to gauge feelings on the matter.

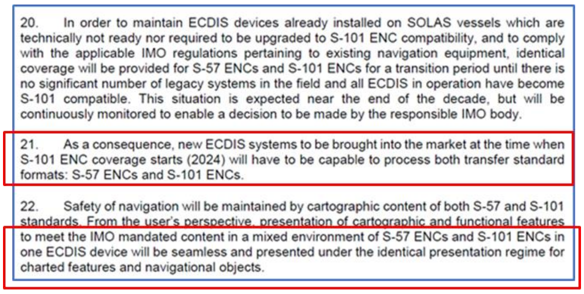
8 Annex - Dual fuel ECDIS (DF-ECDIS)

8.1 Introduction ; Notes from S-100WG5

[these notes were produced following the Dual Fuel ECDIS session at the recent S-100WG5. They represent the combined discussions of the member states (including Canada) at that meeting. They are certainly not authoritative but contain considerations from the IMO/IEC ECDIS community in terms of the operation of ECDIS under both S-57 and S-101 and therefore are relevant when considering co-production of S-57 and S-101 in the transition period]

8.2 DF-ECDIS – What we know now…

An extract from the IHO paper to IMO NCSR is shown below. At the time of writing this summarised the essentials of how Dual fuel ECDIS should operate.



20. In order to maintain ECDIS devices already installed on SOLAS vessels which are technically not ready nor required to be upgraded to S-101 ENC compatibility, and to comply with the applicable IMO regulations pertaining to existing navigation equipment, identical coverage will be provided for S-57 ENCs and S-101 ENCs for a transition period until there is no significant number of legacy systems in the field and all ECDIS in operation have become S-101 compatible. This situation is expected near the end of the decade, but will be continuously monitored to enable a decision to be made by the responsible IMO body.

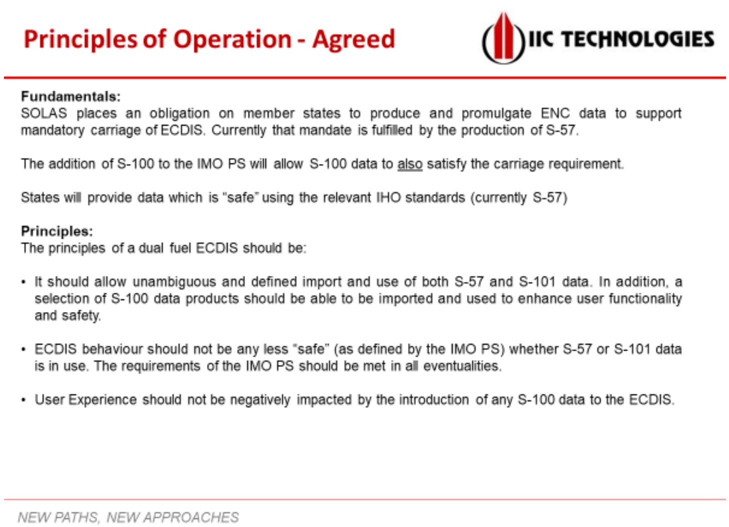
21. As a consequence, new ECDIS systems to be brought into the market at the time when S-101 ENC coverage starts (2024) will have to be capable to process both transfer standard formats: S-57 ENCs and S-101 ENCs.

22. Safety of navigation will be maintained by cartographic content of both S-57 and S-101 standards. From the user's perspective, presentation of cartographic and functional features to meet the IMO mandated content in a mixed environment of S-57 ENCs and S-101 ENCs in one ECDIS device will be seamless and presented under the identical presentation regime for charted features and navigational objects.

NCSR paper extract

8.3 Basic Principles of Operation.

The slide on principles of operation of the DF-ECDIS is shown below:



8.4 Fundamentals (text)

Fundamentals;

- SOLAS places an obligation on member states to produce and promulgate ENC data to support mandatory carriage of ECDIS. Currently that mandate is fulfilled by the production of S-57.

- The addition of S-100 to the IMO PS will allow S-100 data to also satisfy the carriage requirement.
- States will provide data which is "safe" using the relevant IHO standards (currently S-57)

Principles:

The principles of a dual fuel ECDIS should be:

- It should allow unambiguous and defined import and use of both S-57 and S-101 data. In addition, a selection of S-100 data products should be able to be imported and used to enhance user functionality and safety.
- ECDIS behaviour should not be any less "safe" (as defined by the IMO PS) whether S-57 or S-101 data is in use. The requirements of the IMO PS should be met in all eventualities.
- User Experience should not be negatively impacted by the introduction of any S-100 data to the ECDIS.

8.5 Portrayal and ECDIS behaviour.

It is clear (and a reasonably clear consensus within the room supported) that.

1. Display of S-57 and S-101 ENC will NOT be identical.
2. Behaviour of the ECDIS between S-57 and S-101 will NOT be identical.

One of the key observations from the OEM community within the group session was that "we've been doing dual fuel for years" – the concept of ECDIS supporting multiple product types, whether Raster/Vector or DNC/ENC or overlays has been in existence for many years and the Dual Fuel ECDIS concept is merely an extension of that to an upgrade in the ENC "format" to support the introduction of S-100 to the type approval regime.

9 Principle of Separation of S-57 and S-101

The acceptance of the basic principles governing Dual Fuel ECDIS operation and the existence of DF-ECDIS operation led to a more general principle that :

"DF-ECDIS functionality should, in general, be split between legacy S-57 data and operations involving S-101. This will effectively partition the ECDIS operation between the two fundamental ENC products acceptable under the IMO regime during the transition period "

This basic principle can be used to define how the DF-ECDIS will operate as well as implications for data producers.

9.1 ENC Coverage aspects.

There was much discussion around ENC coverage. The basic idea of the partitioning of the ECDIS strongly implies that the existing ENC "overlap rule" (no overlaps between cells within the same usage band) should be extended to the two ENC formats.

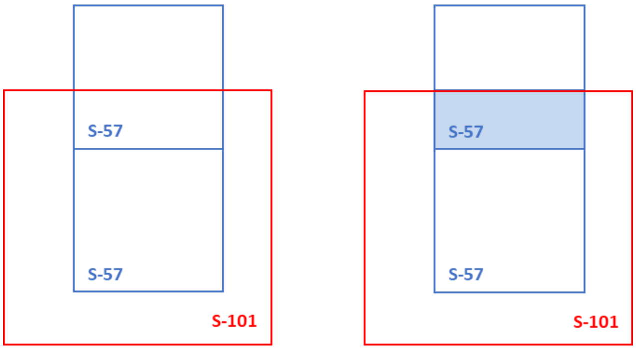
"S-57 ENCs and S-101 ENCs should not overlap. Overlap would be defined as overlapping coverage (other than equivalent cells) at the same compilation scale (CSCL) and maximum display scale of data coverage features".

Data without overlaps of this nature would effectively partition the internal SENC into areas of legacy S-57 data and S-101 data coverage features.

Key to this idea is that the ECDIS determines what to load based on the coverage (and, optionally, the Part 15 permits) presented to it. <u>If presented with data which overlaps it should always import the S-101 data by default</u>.

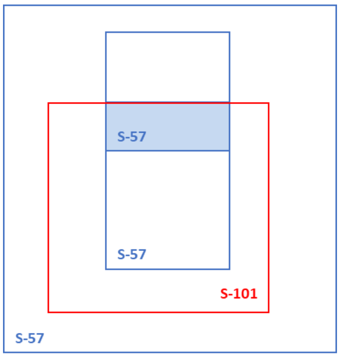
Therefore if an S-101 dataset partially overlaps with a neighbouring S-57 dataset the S-57 dataset will NOT be imported. A simple example is illustrated in the diagram where the S-101 (in red) are compiled and produced in parallel with existing S-57 ENCs. When presented to the ECDIS the S-101 data is loaded on the DF-ECDIS whereas legacy ECDIS loads the S-57 versions of the data.

Conversely when presented with the following datasets (assumed all to be of the same CSCL/max display scale)



In this case the coverage (left) consists of two S-57 cells and a single S-101 cell which partially covers the northern S-57 cell. In this case the DF-ECDIS would only load the S-101 cell and would not truncate the northern S-57 cell to fill in the rest of the coverage. The area of overlap (the southern region of the S-57 cell coloured in blue on the right stops the S-57 cell from being imported to the system.

It would be possible, in this case to fill in the missing area with smaller scale data, as shown in the following diagram:

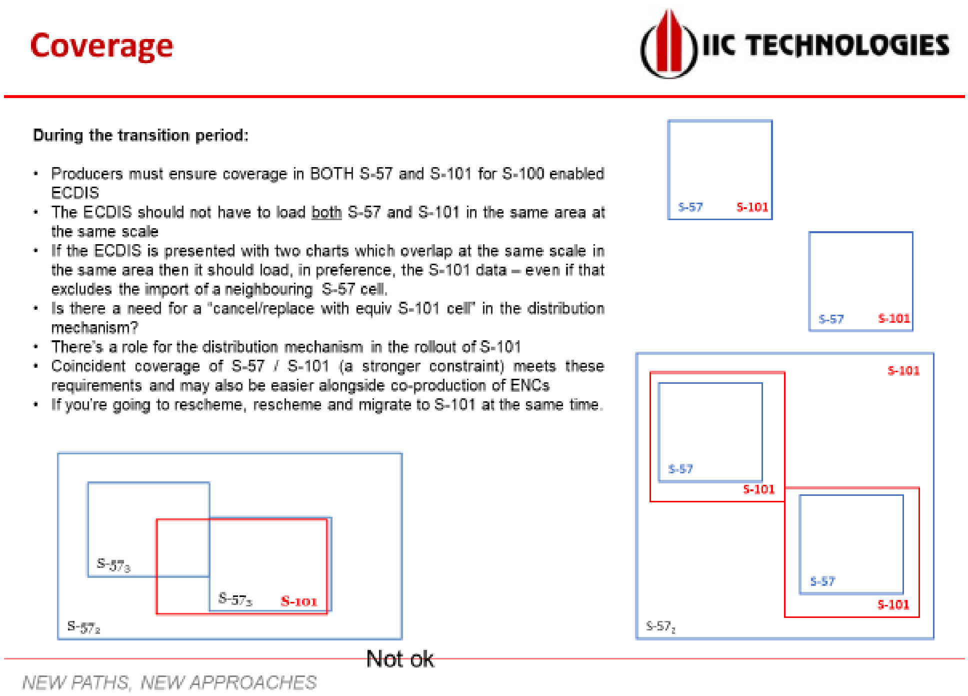


In this case the DF-ECDIS would only load the S-101 data and the smaller scale S-57 data. So the northern half of the S-57 cell is only available at a smaller scale on the DF-ECDIS. While this means the DF-ECDIS may not enjoy full data coverage at the same scale this may well be acceptable to the data producer.

This offers data producers some options in terms of its coverage then. It is possible to produce S-101 with "different" coverage as seen but it relies on the producer being aware of what the behaviour of the ECDIS will be when presented with combined S-57/S-101 datasets.

Does this imply "coincident coverage" where the S-101 ENCs are of identical extent to the S-57 ENCs? This may well be the easiest option in terms of scheming new S-101 coverage but it does offer options where this may need to be modified based on data producer requirements (i.e. new survey, rescheming etc…). in particular, coverage could be aggregated, so (in order to take advantage of the updated 10Mb rule for S-101 ENCs, coverage of two cells could be combined into a single S-101 cell.

This defined operation of the DF-ECDIS is intended to ensure it is never presented with overlapping S-57/S-101 data by a data producer and its display of ENC data can be unambiguous. The SENC is, effectively partitioned and this enables the general DF-ECDIS operation to be approached from the same perspective, i.e. partitioned between S-101 and S-57.



The discussion in the group also suggested that a more formalised "cancel/replace" mechanism, similar to the existing ENC one could be proposed which would give the ECDIS more guidance on which S-57 cells are being "replaced" in coverage by S-101 cells. This would make it clear which cells are intended to replace the S-57 coverage (and eliminate those equivalents from the "overlap" rule).

There is an implicit role for the distribution chain (and RENCs) which should be noted. There are many different roles supporting the operation of DF-ECDIS, notably validation and harmonisation between the two different ENC forms.

10 DF-ECDIS functionality

10.1 Display

Display of ENC should be done "side by side" on the DF-ECDIS. As the SENC is partitioned spatially (and by scale) there is no ambiguity in the operation in terms of which features are being displayed at any point. In particular

1. ENC display is not expected to be identical between S-57 and S-101. The differences should be minimal but even a simple examination of the respective feature catalogues will show where minor differences exist. The overall principle holds, though, that the user experience absolutely will not be negatively impacted (and the absolute intention is that it is positively enhanced)
2. There may well be a need for a "border" between S-57 and S-101 data visible on screen to the user.
3. No implicit conversion of either data or portrayal model should be done on the DF-ECDIS in any case. The partitioning of the SENC into mutually exclusive S-57 and S-101 coverage should extend, in principle also to display of the data – the S-57 data should use the entire existing S-52 structure and the S-101 data should use the S-101/S-100 portrayal mechanisms.

10.2 Feature interrogation

Other ECDIS fucnctionality should be similarly partitioned. Feature interrogation, for example should use existing S-52 mechanisms for legacy S-57 data loaded to the system and S-100 mechanisms for S-10 data. This will result in different user experiences between the two fuels although the observation was made that the S-57 data model driving feature interrogation is a proper subset of the S-100 model and therefore OEMs may be able to develop a more harmonised user experience which meets both standards simultaneously.

10.3 S-10X

Other S-10X product specification data – a requirement was noted to be able to overlay S-10X data on BOTH S-57 and S-101 data but to only extend the functionality of the interoperability specification to areas where S-10X overlaps with S-101 data (and also to potentially partition the S-10X into discrete coverages over the S-57/S-101 data. This would present simpler processes for the DF-ECDIS.

11 Outputs

A general lack of "definition" was noted over DF-ECDIS. What appears to be required is:

1. A general definition document detailing how DF-ECDIS operates, the governing principles (such as those outlined in this document) and the impacts on data producers, the distribution chain and OEMs who construct ECDIS. This should reference and expand on the provisions within the IEC/IMO formal support for S-100. Some of the content of this

document can be used to form an initial version of this document (it is currently unclear where in the IHO ecosystem this should fit however)

2. The operation of the IHO data protection scheme, which governs the importing of data and most of the “packaging” elements of ENC data should be considered “holistically” by the community supporting DF-ECDIS in order to ensure support for the introduction of S-57/S-101 data to the end users. S-100 Part 15 allows for a much finer granularity in user roles and the ability to distinguish between them within the content of the certificate files embedded in the digital signatures. Separate discussions within the S-100WG meeting reinforced the requirement to use such granularity for dual fuel operations. This should also cover renewal and expiry of certificates by the individual participants of the scheme.
3. A related action is required to locate the type approval-specific elements of display and operation currently with the existing IHO standards base (predominantly S-52 and S-64) and ro replicate them within the new testing and product specification defining S-101 ENCs.

12 Data Production Guidance.

More guidance for data producers on ENC rollout will need to be delivered in conjunction with the definition of Dual Fuel ECDIS. As the definition matures, clearer guidance will be an output to data producers (and the distribution chain).

In line with the observations in this document that SENC, portrayal and ECDIS behaviour will not be identical in a dual fuel ECDIS, what is clear at this point is there is currently no easily definable 1-1 correspondence between ENCs in S-57 and S-101 form. They arise from different registers of features/attributes and relationships and from different encoding conventions (UOC vs DCEG). Early ENC conversion studies have pointed out these differences and noted that conversion (and its outputs) are partly dependent on the functionality of the converter and (more difficult) the individual encoding and attribution of the source chart by the data producer (whether attempting to convert S-57 to S-101 or vice versa).

What seems likely is that data producers will need to embark on a “migration” of their existing database (whether database or file-based) in order to support the production of both S-57 and S-101 data. This transformation of data is yet to be defined either in overview or in detail. Certainly there are numerous opportunities to guide this transformation process and to ensure that the impacts on member states are manageable in the run-up to the beginning of the transition period. In this light, while ENC conversion may undoubtedly form part of this broader “migration” to S-101 from an existing S-57 database the process is one of transformation rather than 1-1 conversion.