New perspectives on indigenous navigation tradition

An article by INGO HENNINGS

Stick charts are a significant part of the Micronesian Marshallese navigation tradition in the Pacific Ocean. The islanders navigated without instruments just by observing, among others, oceanic phenomena such as swells, currents, and roughness characteristics of the sea surface. For a long time, the explanation of the various sticks of such latticework remained secret and something of a mystery and was only obtained by oral transmission under great difficulties. Old and new interpretations of stick charts are compared and presented. Signatures of different swells manifested on stick charts were identified and proved by satellite remote sensing data. Current research on indigenous navigation is growing to conserve such unique tradition in the Pacific and especially in the sea area of the Marshall Islands. For scientific research on indigenous navigation knowledge collaboration between natural scientists and ethnologists is necessary.

Marshall Islands | stick charts | swell diffraction | neutron diffraction | CHRIS satellite image

Author

Dr. Ingo Hennings is staff scientist at GEOMAR Helmholtz Centre in Kiel working in the field of Paleoceanography

ihennings@geomar.de

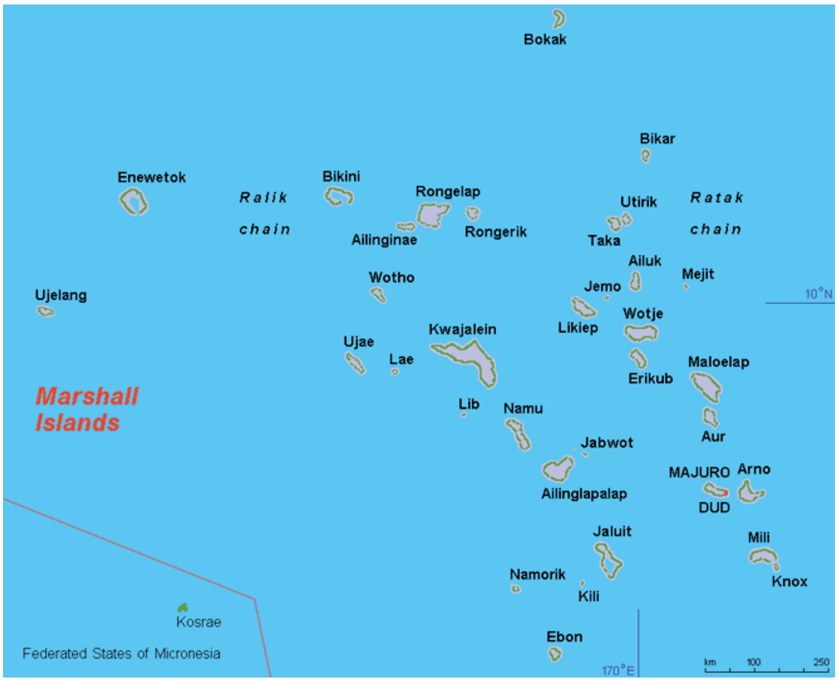
1 Introduction

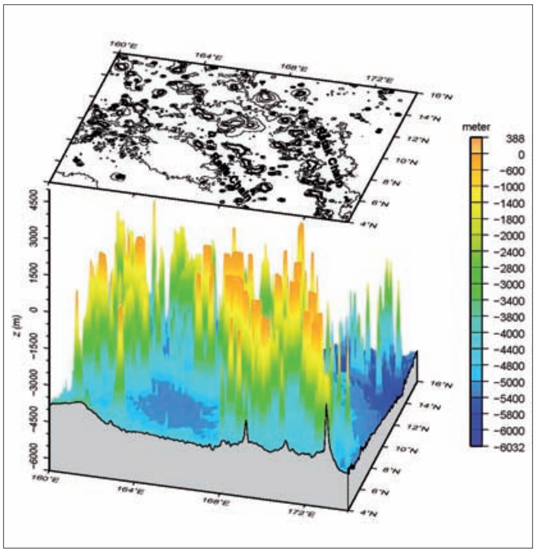
Many small island nations worldwide are vulnerable to sea level rise due to global climate change. An accelerated rise in sea level would further threaten human and natural resources with inundation, coastal erosion, increasing flooding, loss of fresh water and arable land. Environmental disasters, such as typhoons, generate wave fields with significant wave heights of more than 10 m washing across an entire islet, swamping groundwater lens with salt water, causing enhanced salinity concentration and thus imperilling human survival (Spennemann 2006). Climate change could result in major lifestyle changes, threatening or losing a nation's cultural identity and economic growth potential.

The article focusses on the Republic of the Marshall Islands (RMI) in the north-west equatorial Pacific Ocean. This small atoll nation is comprised of 29 atolls and five islands, with an average elevation of less than 2.4 m. The Marshall Islands are aligned in two island chains running roughly NNW to SSE: the western Ralik Chain and the eastern Ratak Chain. A geographical map of the Marshall Islands with the names of islands and atolls is shown in Fig. 1. Different newspaper articles and television contributions in 2009 reported about the loss of atoll ground of up to 40 m on the Likiep atoll of the Ratak Chain since 1995. If the Marshallese people were to be resettled not only the islands but also their traditional way of life would vanish subsequently.

Two- and three-dimensional bathymetric charts of the sea area around the Marshall Islands of Micronesia in the Pacific Ocean are shown in Fig. 2. The source of the data set is »The GEBCO_08 Grid«, version 20100927 (GEBCO is the abbreviation for General Bathymetric Chart of the Oceans). The

Fig. 1: Map of the Marshall Islands with names of islands and atolls. DUD is the abbreviation for Delap-Uliga-Derrit, a major population centre





Source: The GEBCO_08 Grid, version 20100927

Fig. 2: Two- and three-dimensional bathymetric charts of the sea area around the Marshall Islands of Micronesia in the Pacific Ocean

data were visualised by using the Generic Mapping Tools (GMT) software. Fig. 2 shows that the islands and atolls arise almost vertically upwards like needles from the deep ocean basins. Such morphological features cannot be detected by repeated vertical soundings for navigation and a boatman could not be warned in time when entering shallow sea areas. This could be one reason why sounder techniques are not known and used by the islanders of the Marshall Islands when approaching an atoll from the deep open ocean. Therefore, the islanders navigated, among others, by using oceanic phenomena such as swells, currents, and roughness characteristics of the sea surface. On the other hand the draft of an outrigger canoe is small, which implies that sounder techniques are not relevant and not used for navigation purposes.

The islanders of the Micronesian Marshall Islands made simple latticework for the purpose of practical navigation which is known as stick charts. Stick charts are a significant part of the Marshallese navigation tradition. An example of a RMI stick chart, a so-called group chart or *rebbelib,* is shown in Fig. 3 (Krämer and Nevermann 1938). The original of this stick chart (No. 393:10) is presented at the Museum für Völkerkunde (Museum of Ethnology) Hamburg. The general chart *(rebbelib)* shown in Fig. 3 based on explanations given by Paul Hambruch (1912) is presented in Fig. 4 (Krämer and Nevermann 1938). The registered sailing instructions are valid for journeys starting from Djalut (Jaluit).

The widespread corpus of stick chart illustrations was published by Marcia Ascher (1995). She studied models and maps from the Marshall Islands and also wave dynamics that they incorporate. It turned out that the collaboration between natural science and ethnology is necessary especially for the interpretation of indigenous navigation using stick charts. One early example of a natural scientist as well as ethnologist was the German Paul Hambruch (1882–1933). He was a participant of the second part of the Hamburg South Sea expedition 1909–1910 and first head of the South Sea department at the Museum für Völkerkunde (Museum of Ethnology) Hamburg, Germany (Fischer 1981). During life he kept the connection between natural science and ethnology. At that time, ethnologists and natural scientists took a long time to find explanations for the interpretation of stick charts used on the Marshall Islands as one important nautical aid to sail from one atoll to another. Today, again ethnologists, oceanographers, and natural scientists take time to understand and describe the effect of global climate change, also possibly responsible for the disappearing of the Marshall Islands beneath the ocean with all their unique cultures. Fortu-

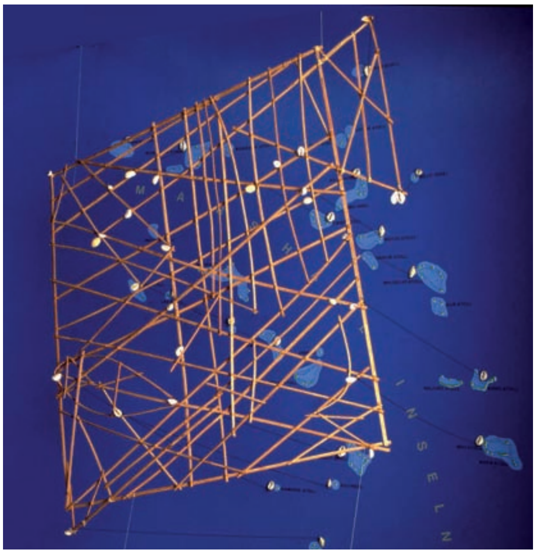
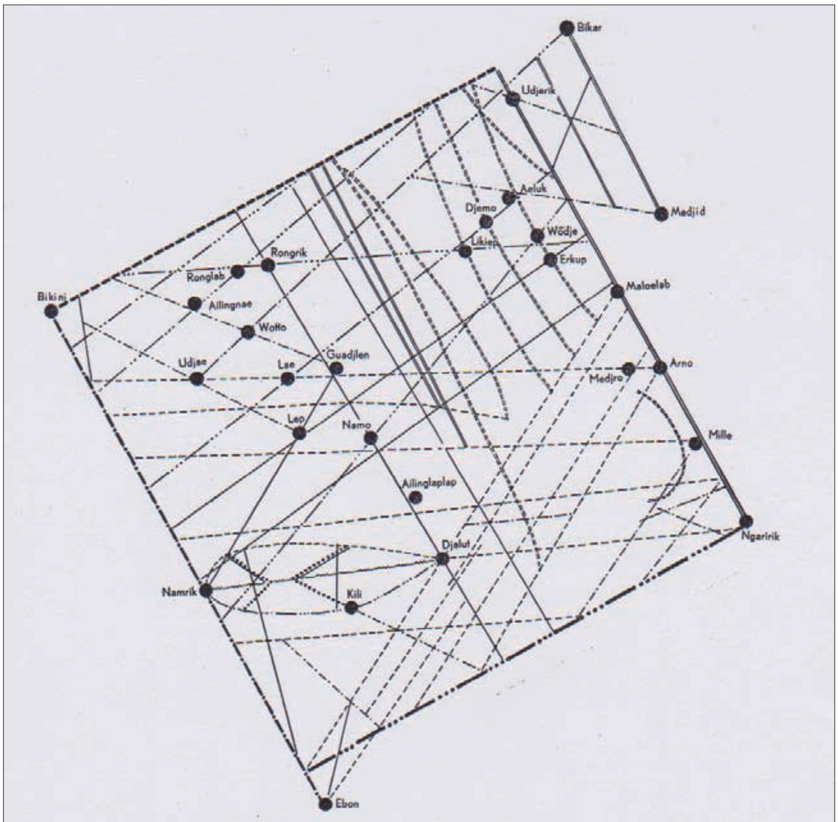


Fig. 3: Stick chart of the Marshall Islands represented as a group chart or *rebbelib*. The original of this stick chart (393:10) is present at the Museum für Völkerkunde Hamburg



Explanations according to Paul Hambruch (1912):

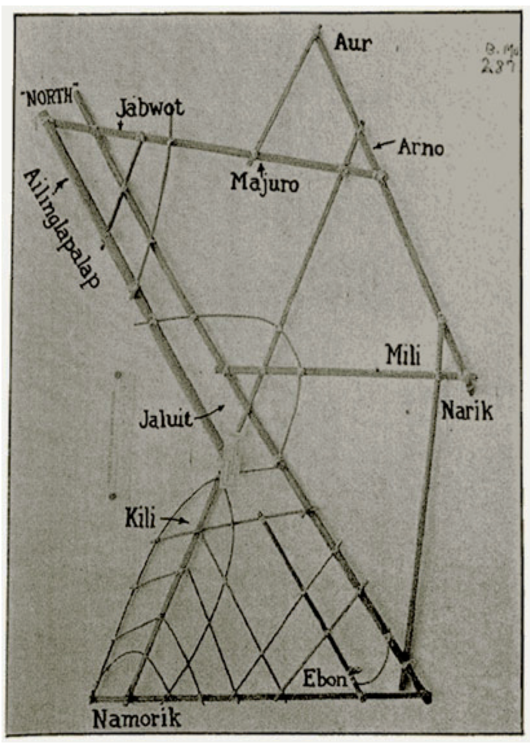
--- . . . --- . . . SE- respectively S-swell, very weak
- - - - - - - NW- respectively N-swell, weak
--- . --- . --- . SW- respectively W-swell, strong
======= NE- respectively E-swell, very strong
________ line of knots, intersection of deflecting N- and S-swell
. . . . current of the seasons, monsoon- respectively trade-wind seasons, from the Island alternating leading off diagonal of the swell square
. . . . to the island leading diagonal of the swell square, choppy sea 10-15 sea miles from the approaching island
--- . . . --- ... region of the deflecting swell
------------ region of the deflecting swell
_ . _ . _ . _ region of the deflecting swell
= = = = = region of the deflecting swell

Fig. 4: General chart *(rebbelib)* shown in Fig. 3 with explanations (Hamburg, No. 393:10, scaled down (Krämer and Nevermann 1938)). The registered sailing instructions are valid for journeys starting from Djalut (Jaluit)

nately, museums of natural history and ethnology worldwide will show influences, effects, and interactions on atoll cultures of Oceania due to global climate change. For example, the Grassi Museum für Völkerkunde zu Leipzig (Museum of Ethnology) and the Linden-Museum Stuttgart, both located in Germany, are planning to show effects and interactions between atoll cultures in the Pacific Ocean and global climate change. Some of these new exhibition conceptions are already partly realised. The Museum für Völkerkunde (Museum of Ethnology) Hamburg presents unique objects collected during the Hamburger Südsee-Expedition 1908–1910 which could also be the starting point of a new view on traditional navigation in Micronesia.

Old traditions of the Marshall Islands are revived presently. Genz and Finney (2006) described how cultural anthropologists and other professionals in Oceania can help their host countries in reaching their historic preservation goals for an intangible cultural heritage. They reflect the philosophy of their current research on indigenous navigation in the Republic of the Marshall Islands. Similarities and differences between indigenous and Western scientific knowledge in the sea area of the Marshall Islands have been shown by Genz et al. (2009). Their oceanographic perspective conformed strongly with one indigenous concept of a lee-wave crossing pattern resulting from refraction of the easterly trade wind swell.

The aim of this article is the remembrance of such unique navigation traditions in the light of new perspectives so that they do not fall into oblivion and will be preserved. A brief description and interpretation of stick charts are given in section 2. In sections 3 to 5 three examples are presented, in which western scientific and traditional ecological knowledge is combined having benefits beyond simply relying on one or the other, for reasons, to make atoms and atolls visible, to superimpose two different swells by using their trajectories, and to identify signatures of different swells on satellite images. Finally, the summary is given in section 6.



Source: Gulick 1862; Schück 1902, Fig. 31

Fig. 5: Stick chart *(rebbelib)* of the Marshall Islands obtained by the American missionary Luther H. Gulick in 1860

2 Interpretation of stick charts

A brief paragraph of stick charts of the Marshall Islands was published by the American missionary Luther H. Gulick and first caught public attention in 1862 (Gulick 1862). Gulick obtained two stick charts in 1860, possibly from the Ebon atoll, which are now exhibited in the Bernice Pauahi Bishop Museum, Honolulu, Hawaiian Islands, USA. One of the two stick charts, so-called group charts or *rebbelib,* is shown in Fig. 5. The Marshall Islanders sailed with outrigger canoes between the atolls and on the open sea. An impression of Marshall Islands canoes from Jaluit is presented in Fig. 6 (Hernsheim 1883). A short description of navigation and utilisation of stick charts was published by Friedrich Ratzel (1886). Captain Raimund Winkler, commander of the German wooden sheathed light cruiser »S.M.S. Bussard« received first information of the interpretation of stick charts in 1896/97 on Jaluit of the Marshall Islands (Winkler 1901). The counterpart of European naval sea going vessels at that time is demonstrated by the picture of »S.M.S. Bussard« built for German colonial service shown in Fig. 7. Thomas A. Joyce (1908) reported that the English translation of Winkler's German article (Winkler 1898) was not very polished and in parts almost grotesque. However, Joyce had to confess that he had no current information on that subject and referred to the papers of Winkler (1901) and Albert Schück (1902), which, in general, are valid until today and were often cited. Some details of other five stick charts have been presented by Henry Lyons (1928). Later on, principles and problems presented by the stick charts have been published by William Davenport (1960, 1964) and Kjell Åkerblom (1968).

Here, a brief description of stick charts is given according to the interpretations published by Winkler (1898), Winkler (1901), Schück (1902), Hambruch (1912), Krämer and Nevermann (1938), Davenport (1960), and summarised by The Metropolitan Museum of Art (2008), New York, USA. Stick charts consist of numerous narrow strips of centre-ribs of palm leafs lashed together in a rude latticework and are arranged in certain forms and positions. Cowrie snails, small shells, and small pieces of corals are often fixed with lengths of coconut fibre to the sticks in order to represent the atolls of the archipelago. Coconut fibre was obtained from the fibrous husk *(mesocarp)* of the coconut *(Coco nucifera)* from the coconut palm, which belongs to the palm family *(Palmae).*

In the Marshall Islands, navigation was and remains an essential skill, on which the lives of the navigators and all other passengers depended. In the past, knowledge of the art of navigation was a closely guarded secret handed down within

References

Åkerblom, Kjell (1968): Astronomy and navigation in Polynesia and Micronesia; Stockholm Monograph Series, The Ethnographical Museum, Stockholm, No. 14, 170 pp.

Ascher, Marcia (1995): Models and maps from the Marshall islands: a case in ethnomathematics; Historia Mathematica, 22, pp. 347–370

Davenport, William (1960): Marshall Islands navigational charts; Imago Mundi, 15, pp. 19–26

Davenport, William (1964): Marshall Islands cartography; Expedition, 6, pp. 10–13

Fischer, Hans (1981): Die Hamburger Südsee-Expedition. Über Ethnographie und Kolonialismus; Syndikat Autoren- und Verlagsgesellschaft, Frankfurt am Main, 160 pp.

Genz, Joseph; Ben Finney (2006): Preservation and revitalization of intangible cultural heritage; Micronesian Journal of the Humanities and Social Sciences, 5, pp. 306–313

Genz, Joseph; Jerome Aucan; Mark Merrifield; Ben Finney; Korent Joel; Alson Kelen (2009): Wave navigation in the Marshall Islands – Comparing indigenous and Western scientific knowledge of the ocean; Oceanography, 22, pp. 234–245

Goss, John (1993): The mapmaker's art: an illustrated history of cartography; Rand McNally, Skokie, Illinois, USA, 376 pp.

Gulick, Luther H. (1862): Micronesia of the Pacific Ocean; The Nautical Magazine, 31, pp. 298–308

Hambruch, Paul (1912): Die Schiffahrt auf den Karolinen- und Marshallinseln; Meereskunde: Sammlung volkstümlicher Vorträge zum Verständnis der nationalen Bedeutung von Meer und Seewesen; E. S. Mittler und Sohn, Berlin, 6, 40 pp.

Hennings, Ingo (1999): Imaging of oceanic surface features on radar satellite scenes already indicated on Micronesian stick charts; History of Oceanography Yearbook, 6, pp. 7–18 …

certain leading families. To assist in recalling and imparting aspects of navigational knowledge, navigators constructed diagrams representing different portions of the archipelago. Made from the sticklike midribs of coconut palm fronds, these objects were memory aids, created for personal use or to instruct novices, and the significance of each was known only to its maker. The charts were exclusively used on land, prior to a voyage. To carry one at sea would put a navigator's skill in question.

The charts indicate the position of islands, but they primarily record features of the sea. Marshallese navigation was based largely on the detection and interpretation of the patterns of ocean swells. Like as a stone thrown into a pond produces ripples, islands after the orientation of the waves that strike them, create characteristic swell patterns that can be detected and used to guide a vessel to land. It is the presence and intersection of swells and other aquatic phenomena, such as currents, that are primarily marked on stick charts.

3 Visibility of invisible atoms and atolls

The content of a stick chart is viewed from a new perspective if the following two responsible physical mechanisms, of how to make atoms and atolls visible, are compared. Swell diffraction due to islands or atolls can be illustrated today by analogical physics like neutron diffraction due to particles (Paul Scherrer Institut 2009). Both mechanisms make invisible atolls and atoms visible. By using the experimental method of neutron diffraction it is possible to make atoms visible, for example in material research. A neutron can also behave like a wave. The interaction of neutrons with atoms is analogous to the interaction of swell waves with atolls of the Marshall Islands. Due to such interactions interference patterns arise. From the interference patterns of neutrons conclusions can be made about the structure and movement of atoms. Analogically to neutron diffraction the inhabitants of the Marshall Islands could find the position of an invisible atoll following the knots *(okar)* of different swell patterns by observing them from on board their outrigger canoes. The concept of neutron and electron diffraction applies in the same manner to Bragg diffraction or Bragg formulation of X-ray diffraction. As a first approximation Bragg scattering is the primary mechanism for describing the backscattering of radar pulses from the sea surface and therefore different oceanographic and meteorological phenomena can be made visible like long waves, internal waves, submarine bottom topography and ocean fronts (Hennings 1999).

4 Superposition of swell trajectories

Under the condition that an atoll can be considered here as a homoclinic fixed point in phase space the following example described by Nolte (2010) is presented. The superposition of two different swells by using their wave trajectories looks just like a lattice-work of knots *(okar)*. Henri Poincaré (1854 to 1912) already discovered a comparable counterpart of such lattice-work during his study of the three-body system in phase space. Nolte (2010) summarised this discovery as follows (p. 38):

»In the course of correcting his mistake [of a submitted paper for publication in *Acta Mathematica* (the paper was already through proofs and initial printing late in 1889) from December 1889 to January 1890], Poincaré took a geometric approach in which he visualized the behavior around a special feature of the motion called a homoclinic fixed point – a saddle point where stable and unstable trajectories intersect in phase space. As he studied the solutions, he discovered that the trajectories would cross an infinite number of times. It was that ›tangle‹ (…) that was generating the arbitrarily large response to small changes in initial conditions that he had discovered. He was amazed by his own findings:

›If one seeks to visualize the pattern formed by these two curves and their infinite number of intersections (…), these intersections form a kind of lattice-work, a weave, a chain-link network of infinitely fine mesh; each of the two curves can never cross itself, but it must fold back on itself in a very complicated way so as to recross all the chain-links an infinite number of times.

One will be struck by the complexity of this figure, which I am not even attempting to draw. Nothing can give us a better idea of the intricacy of the three-body problem, and of all the problems of dynamics in general.‹

It was clear to him that he had discovered a fundamentally new aspect of dynamical motion. That was the original discovery of what is today known as sensitivity to initial conditions, which is at the heart of chaos theory.«

Source: Hernsheim 1883

Fig. 6: Impression of Marshall Islands canoes from Jaluit

© www.kaiserliche-marine.de

Fig. 7: Picture of the German light cruiser »S.M.S. Bussard« built for colonial service; launching: 23 January 1890 in Wilhelmshaven, Germany; length: 76 m, displacement: 1570 tons

…
Hernsheim, Franz (1883): Südsee-Erinnerungen (1875–1880); A. Hofmann, Berlin, IV: 109 pp.
Joyce, Thomas A. (1908): Note on a native chart from the Marshall islands in the British Museum; Man, 8, pp. 146–149
Krämer, Augustin; Hans Nevermann (1938): Ralik-Ratak (Marshall-Inseln). Ergebnisse der Südsee-Expedition 1908–1910; in: G. Thilenius (ed.): II. Ethnographie: B. Mikronesien, Band 11, Hamburg: Friederichsen, De Gruyter & Co., 304 pp.
Lyons, Henry (1928): The sailing charts of the Marshall Islands; The Geographical Journal, 72, pp. 325–327
Nolte, David D. (2010): The tangled tale of phase space; Physics Today, 63, pp. 33–38
Paul Scherrer Institut (2009): Neutronen für die Forschung. Die Spallations-Neutronenquelle SINQ am Paul Scherrer Institut; Paul Scherrer Institut, Villingen, 32 pp.
Ratzel, Friedrich (1886): Die Naturvölker Ozeaniens, Amerikas und Asiens; Völkerkunde, Band 2, Bibliographisches Institut, Leipzig, 815 pp.
Schück, Albert (1902): Die Stabkarten der Marshall-Insulaner; Kommissionsverlag von H.O. Persiehl, Hamburg, 48 pp.
Spennemann, Dirk H. R. (2006): Freshwater lens, settlement patterns, resource use and connectivity in the Marshall Islands; Transforming Cultures eJournal, 1, pp. 44–63 …

…
The Metropolitan Museum of Art (2008): Navigational Chart (Rebbilib), Marshallese people, Marshall Islands (1978.412826); in: Heilbrunn Timeline of Art History; New York, 4 pp.
Winkler, [Raimund] Capt. (1898): Über die in früheren Zeiten in den Marshall-Inseln gebrauchten Seekarten, mit einigen Notizen über die Seefahrt der Marshall-Insulaner im Allgemeinen; Marine-Rundschau, pt. x, pp. 1418–1439
Winkler, [Raimund] Capt. (1901): On sea charts formerly used in the Marshall islands, with notices on the navigation of these islanders in general; Annual Report of the Smithsonian Institution 1899, Washington, D.C., pp. 487–509

5 Visibility of swell signatures on satellite images

In fact, the signatures of different swells, which have been manifested on stick charts by the natives on the Marshall Islands, were indeed identified and proved when the National Aeronautics and Space Administration (NASA) of the USA started their satellite observations of the whole earth surface in the 1970s (Goss 1993). The imaging of oceanic surface features on radar satellite scenes already indicated on Micronesian stick charts was published by Hennings (1999). As an example, Fig. 8 shows the sea area around Swains Island, the northernmost island of American Samoa in the southern Pacific Ocean. The satellite image was acquired from on board the European Space Agency's (ESA's) Project for On-Board Autonomy (Proba) spacecraft on 27 March 2006. The sensor on board of Proba is the Compact High Resolution Imaging Spectrometer (CHRIS), achieving a spatial resolution of 18 m in 19 programmable spectral bands. A dominant north-easterly swell direction is present at the acquisition time of the satellite image. Signatures of different interference patterns of swells as indicated on stick charts are visible on this CHRIS image. The line formed by the cabbeling points, called *okar,* of both swell diffraction patterns south-westerly of Swains Island is marked by two arrows in Fig. 8. The mechanism called cabbeling originated from the German nautical term ›Kabbelung‹ meaning a rippled or choppy structure of the sea surface. The expression *okar* is used here to describe a regularly alignment of *bots,* which are increased choppy seas due to the deflection of swells by the islands itself producing well-defined diffraction patterns. By identifying this *okar* a boatman is able to navigate his outrigger canoe from one island to another if the other island is located in direction of the *okar.* A similar satellite image was presented by Genz et al. (2009) showing an Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) image of Mejit Island from the Marshall Islands. Genz et al. (2009) combined information from a satellite image of the sea area around Mejit Island and results of computer modelling to determine that swell refraction account for that phenomenon. The satellite image and the modelling results indicate how an east swell bifurcates northward and southward around the island due to swell refraction, resulting in a zone of intersecting wave trains in the lee.

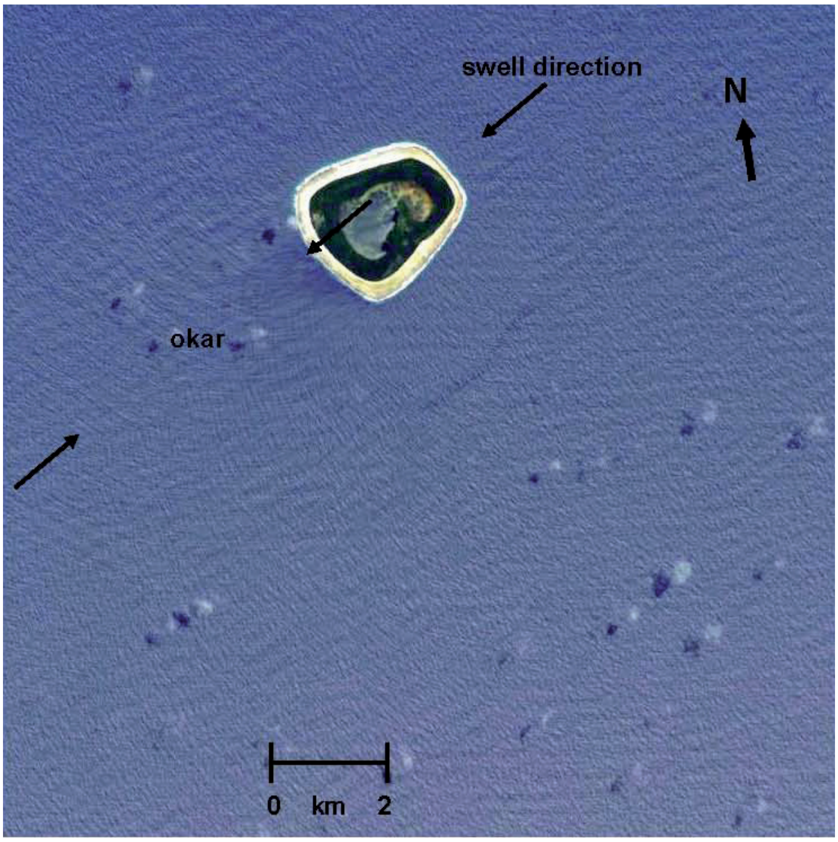


Fig. 8: Modified CHRIS satellite image acquired on 27 March 2006 from on board ESA's Proba spacecraft. Signatures of different interference patterns of swells are visible. The so-called *okar,* the line formed by cabbeling points of two different swells, has been used by Marshall Islanders for navigation from one island to another

Source: www.esa.int/esaEO/SEMNZHRMTWE_index_2.html

6 Summary

When Luther H. Gulick published a first note on Marshallese stick charts in 1862 many people did not believe in these different structures of the water surface used for navigation. However, more than 100 years later, photographs, sun glint and radar data from space borne platforms showed synoptic views of the ocean surface with roughness characteristics caused by dynamical processes of the ocean and atmosphere. These remote sensing data confirmed the patterns indicated within stick charts. Especially interference patterns of swells associated with increased choppy seas around islands have been used by the Micronesians on board of outriggers and guided them from one island to another.

It has been shown that Pacific Islanders have a history of navigating without instruments across vast distances over the ocean to reach other atolls and islands. This art is being revived, with voyaging canoes and Pacific voyagers serving as powerful messengers to raise awareness of the imperilled oceans coordinated by the Pacific Voyagers Foundation. *Vaka moanas,* or ocean going canoes, are sailing across the Pacific, *vaka motus,* or inter-island canoes, are designed for sustainable inter-island transport, and the *vaka hapuas* are built for lagoon and short distance travelling.

Today, it is widely accepted that climate change will threaten the whole human living space. Pacific island countries have contributed just 0.06 % to global greenhouse gas emission. Yet now, changing climate and sea level rise due to global warming are affecting Marshallese water supply, food production, fisheries and coastlines. Although the Marshall Islands are located 13,000 km away from Middle Europe their destiny should also be of our interest. It is promising that different museums of natural history and ethnology worldwide have expanded their main objective to maintain cultural resources and will show influences, effects, and interactions on the atoll culture of Oceania due to global climate change. It is hoped that preservation and revitalisation of intangible cultural heritage of Oceania will survive, because the paradise is defenceless. ⚓