How Japan COULD join land and sea data

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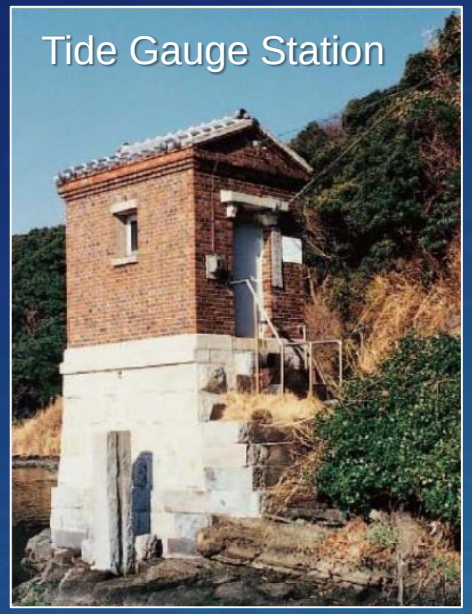
Outline

- Current Height System in Japan
  - ✓ Land: Geodetic Leveling, Tide Gauge Station, Hybrid Geoid
  - ✓ Marine: Hydrographic Survey
- Ongoing and Future Prospects of Height System in Japan
  - ✓ Land: Gravity Geoid, Nationwide Height Update
  - ✓ Marine: Ellipsoidally Referenced Survey
- Challenges
  - ✓ Huge vertical Crustal Deformation
  - ✓ Sea Level Change, the Kuroshio Path Variation

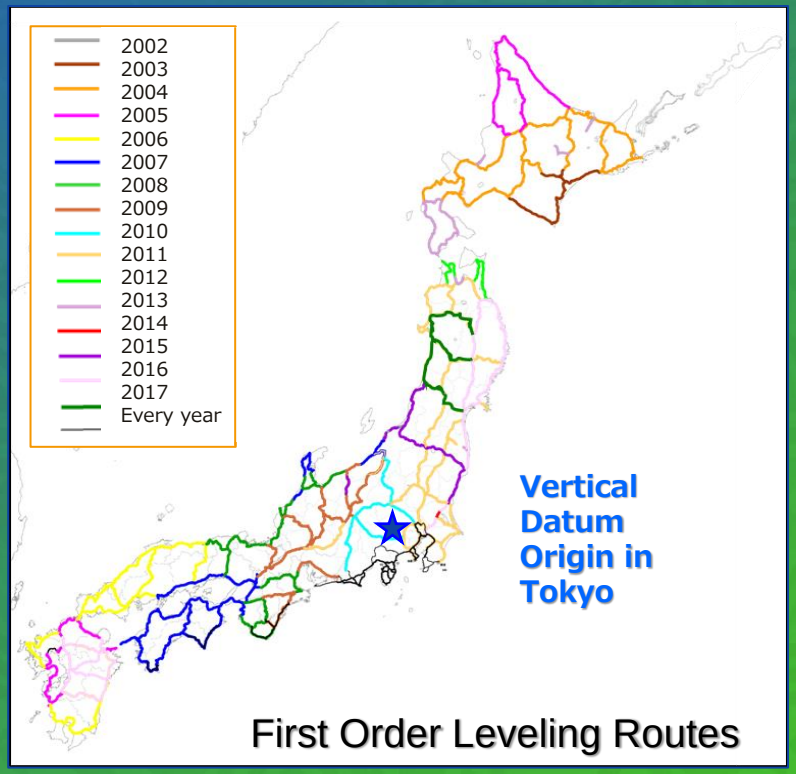
Height System in Japan: Land

- First Order Leveling Routes 14,000km (170,000 benchmarks)
  - ✓ Repeated geodetic leveling campaign since 1983 (10-15 years for one campaign)
- Mean Sea Level in Tokyo Bay
  - ✓ Monitored by Tide Gauge Station since 1894



Vertical Datum Origin in Tokyo
(& GNSS CORS Station)

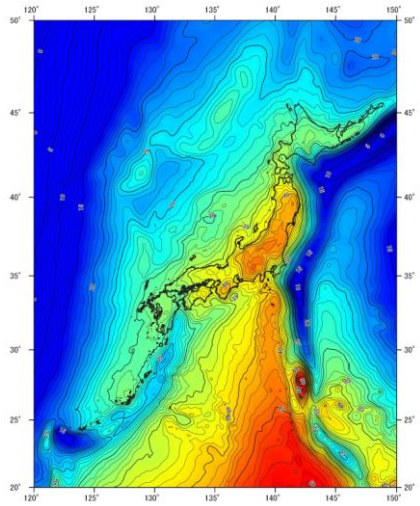
First Order Benchmark



Height System in Japan: Land (Cont.)

- Hybrid Geoid Model of Japan: GSIGEO2011
  - ✓ Gravity Geoid Model fit to GNSS/Leveling geoid height by Least Square Collocation
  - ✓ Fully consistent with orthometric heights of the first order benchmarks

Gravity Geoid Model



JGEOID2008

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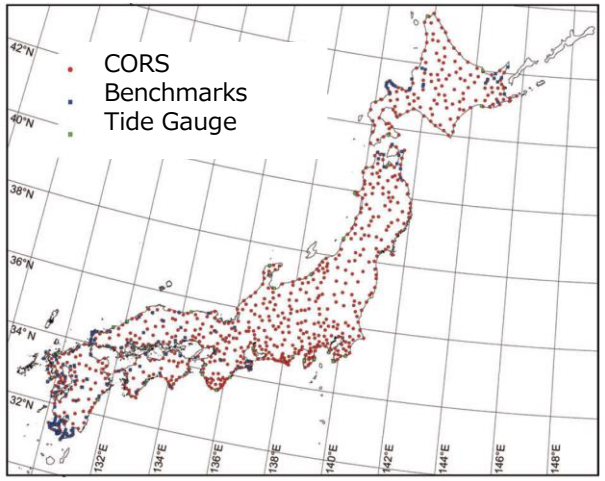
GPSS/Leveling



GNSS/Leveling Geoid Heights

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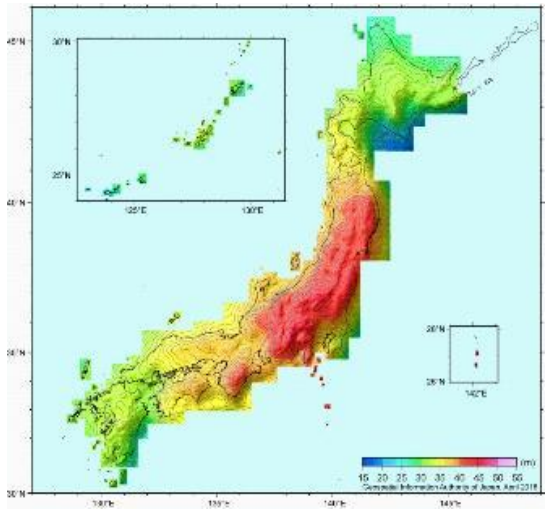
Hybrid Geoid Model

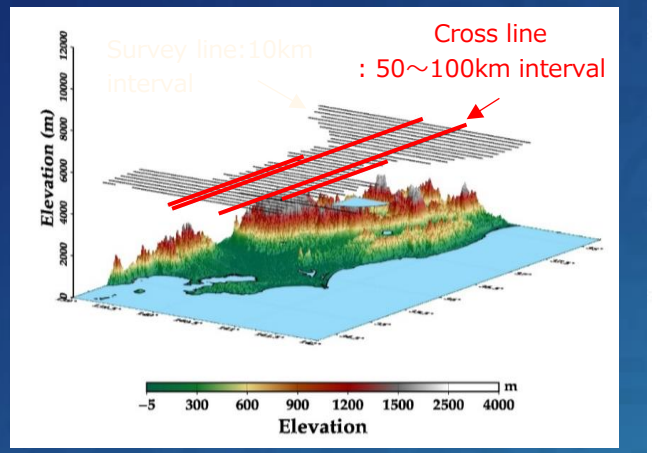


GSIGEO2011

Updates of Height System in Japan: Land

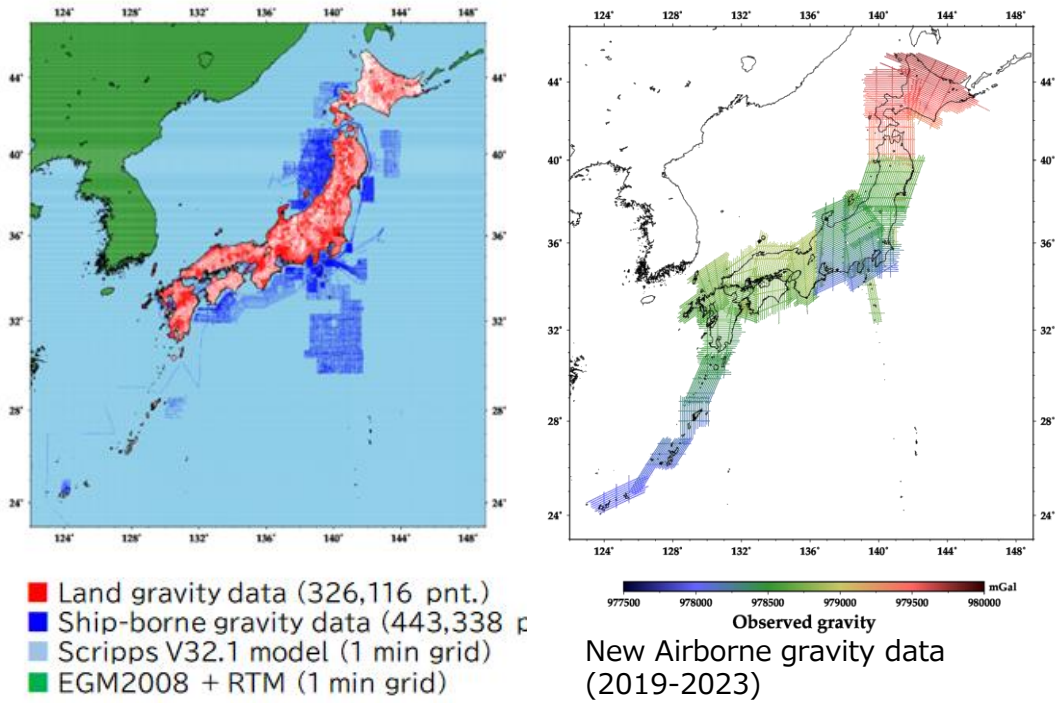
- New Gravity Geoid Model of Japan: JGEOID2024
  - ✓ Nationwide Airborne gravity + land/shipborne/satellite gravity data (+Residual Terrain Model)

Flight altitude
: 3000 - 5000m



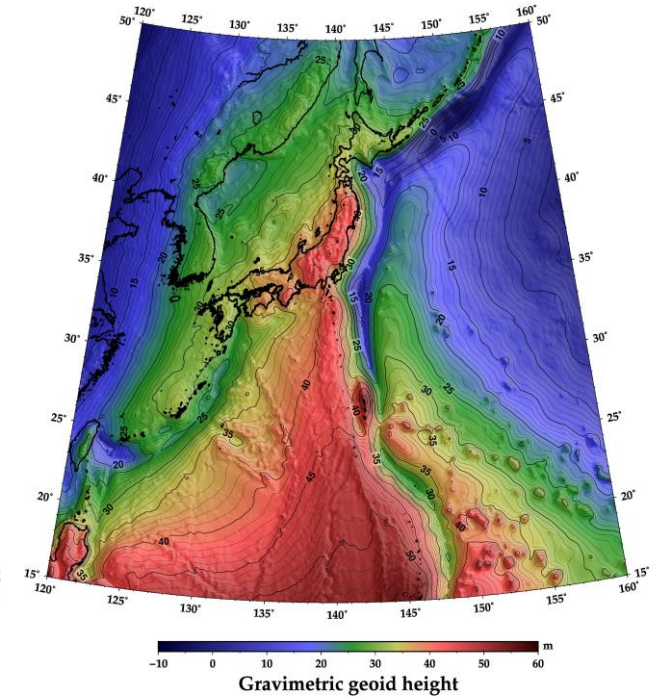
Airborne Gravity Survey

Input Gravity Data Distribution



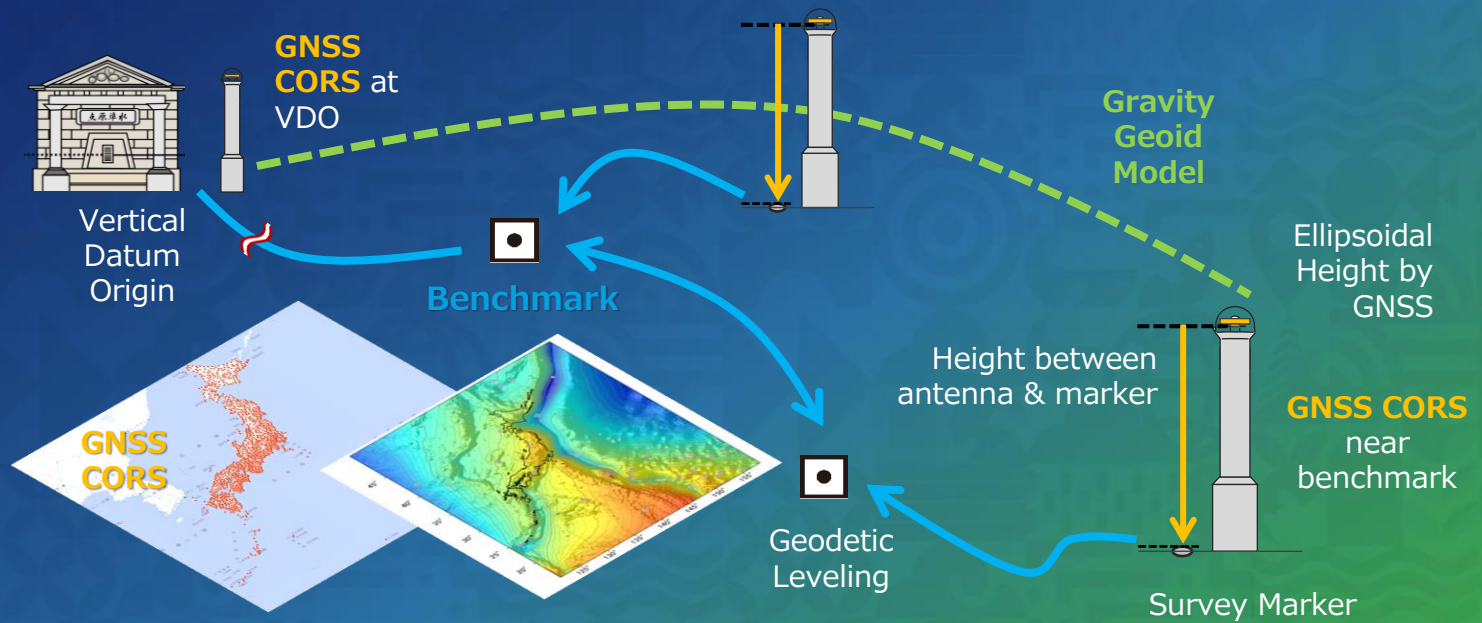
New Airborne gravity data (2019-2023)

JGEOID2024 (Matsuo, in prep.)



Updates of Height System in Japan: Land (cont.)

- Nationwide Height Update planned in April 2025
  - ✓ New height values calculated from gravity geoid model and GNSS ellipsoidal heights
  - ✓ Introduction of new survey method: **GNSS height Survey**
  - ✓ Orthometric height will be determined only from GNSS & gravity geoid model in GNSS height Survey
  - ✓ GNSS CORS will be control points for orthometric height determination

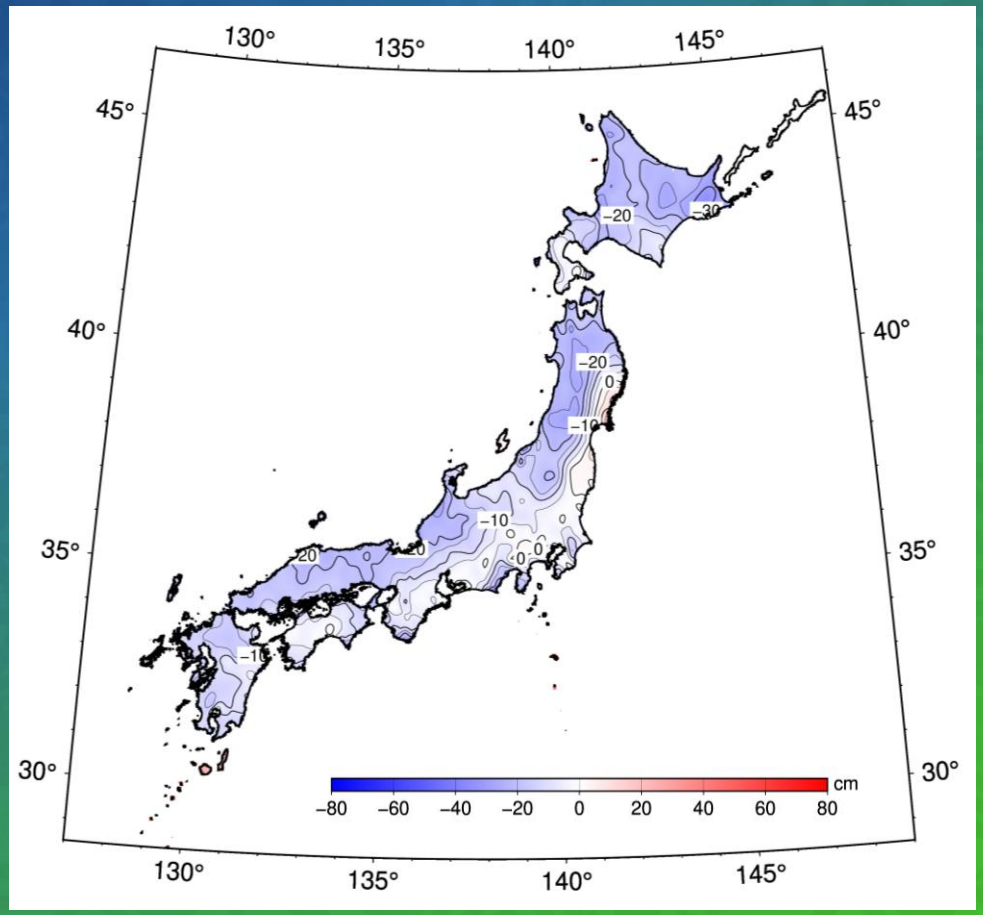


CORS Orthometric Height determination by **GNSS CORS** and **Gravity Geoid Model**

Updates of Height System in Japan: Land (cont.)

- Nationwide Height Update planned in April 2025

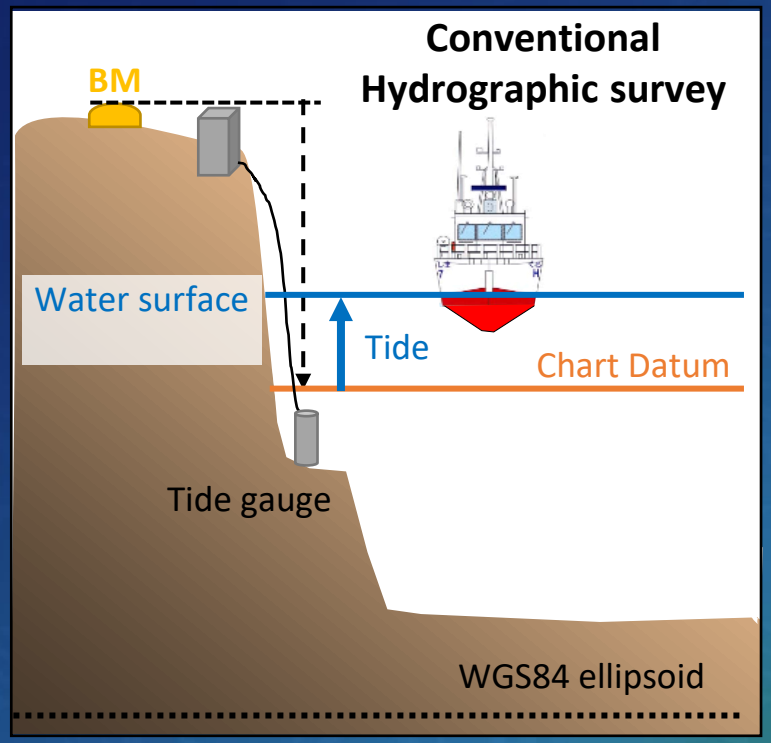
  - ✓ Gravity Geoid Model is first developed to fit to IAG recommendation of W0 (geopotential value of global sea level) and **shifted to fit meal sea level of Tokyo Bay** (local sea level)
  - ✓ Changes of height values at almost all benchmarks and GNSS CORS are negative and maximum change is approximately -30cm



Estimated changes between current and new height values

Height System in Japan: Marine

- Hydrographic Survey
  - ✓ Determine Chart Datum by survey from land benchmark & tidal observation



Conventional
Chart Datum List

Port Name Benchmark Lat Lon Chart datum

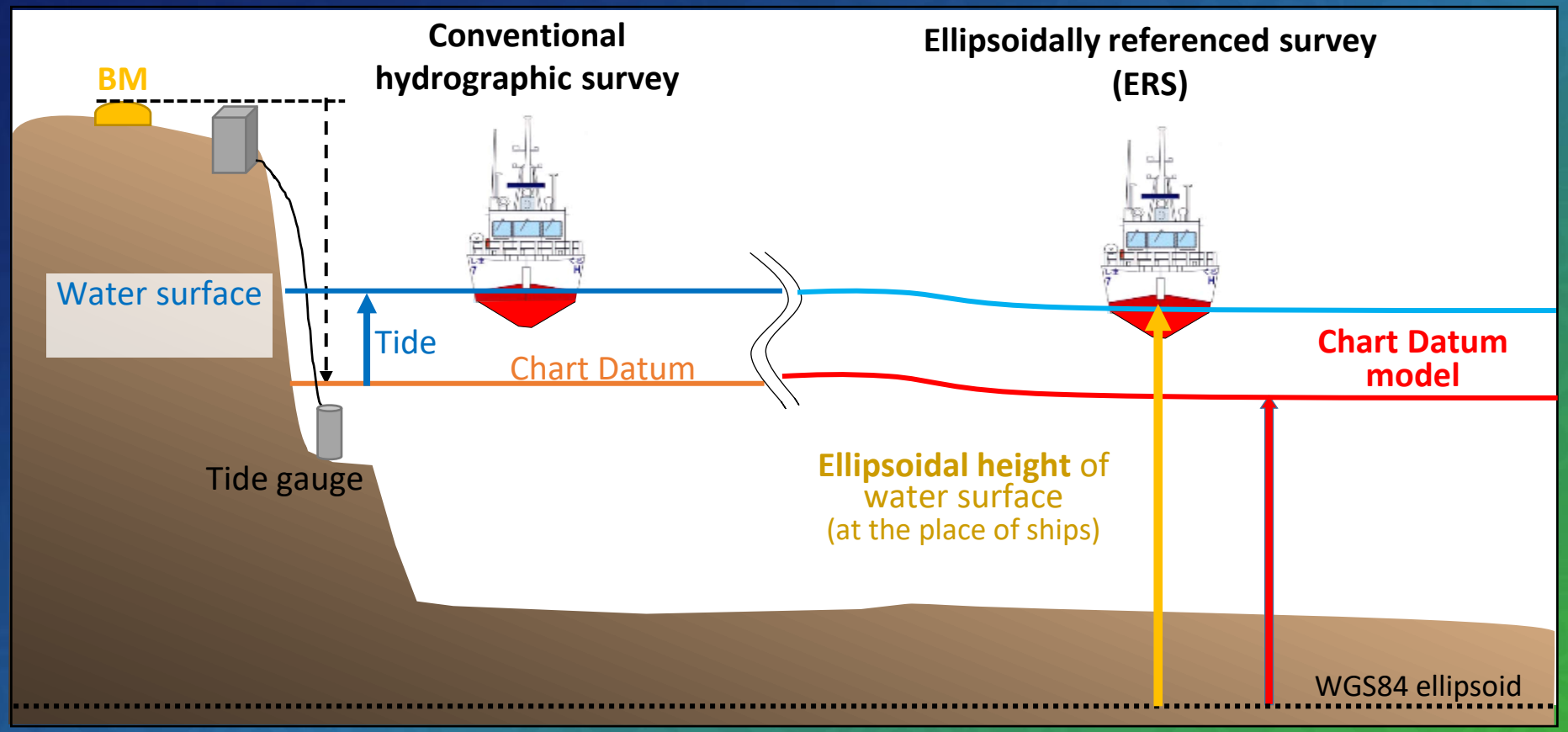
地名又は港名	基本水準標等 所在	位置 緯度(N)	位置 経度(E)	最低水面 採用調査年月	最低水面 最近調査年月	最低水面 基本水準標等下 m	最低水面 平均水面下(Z0)m	最低水面 TP下 m	最低水面 楕円体高 m	最高水面 平均水面上 m
明石	明石験潮所そばにある県BM(金属標)頂	34-39	135-0	平30-11		3.15	0.70		36.42	0.70
	国土地理院BM(441号)頂	34-39	134-59	昭58-08	平07-03	3.74	0.70	0.67		0.70
淡路島										
岩屋	漁業組合南東方約100mの岸壁上面にあるHBM(金属標)頂	34-35-28.4	135-1-0.0	平18-12	平31-03	2.17	0.70		36.34	0.70
野島江崎		34-36	134-59				0.70			0.70
	播磨灘									
淡路島										
室津		34-32	134-52				0.80			0.80
江井	験潮所東方にあるHBM(金属標)頂	34-27-58.2	134-49-41.8	令04-12		2.36	0.80		36.44	0.80
都志	港内にあるHBM(金属標)頂	34-24-53	134-46-48	令03-10		1.90	0.80		36.35	0.80
湊		34-20	134-44				0.90			0.90
引田		34-14	134-24				1.00			1.00
小豆島										
坂手	児島北岸にあるHBM(＋符)	34-26	134-20	昭44-04		2.80	1.00			1.00
大部		34-33	134-17				1.00			1.00
家島		34-41	134-32				0.90			0.90
東播磨										
二見	東二見験潮所付近にあるHBM(金属標)頂	34-41	134-53	平25-11	令04-07	2.09	0.80		36.15	0.80
別府		34-43	134-51	昭45-11			0.80			0.80
高砂	兵庫県験潮所そばにあるHBM頂	34-44	134-48	平30-12	令02-07	4.07	0.90		36.08	0.90
	国土地理院BM(430号)頂	34-46	134-50	平07-06		7.23	0.90	0.86		0.90

Height

Year of Update

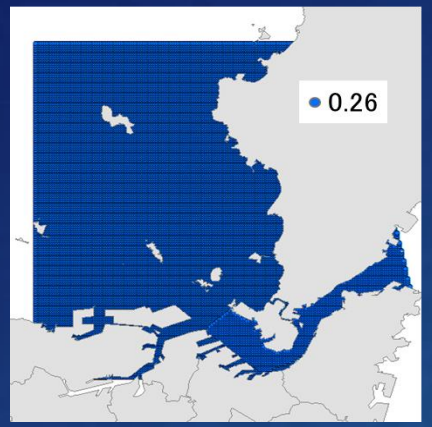
Mirandization of Height System in Japan: Marine

- Introduction of ellipsoidally Referenced Survey
  - ✓ Determine Chart Datum from ellipsoidal height of water surface & Chart Datum model



Mirandization of Height System in Japan: Marine (cont.)

- Development of Chart Datum model is a key
  - ✓ Determine Chart Datum by ellipsoidal height of water surface & Chart Datum model



Mean Sea Level above geoid [m]

"MSL height"

↑

Complicated variation by
- Kuroshio current
- Ground movements

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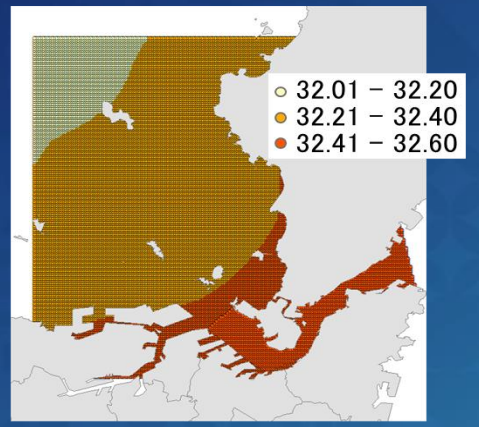

Geoid model[m]

"JGEOID" (gravity geoid) published by GSI

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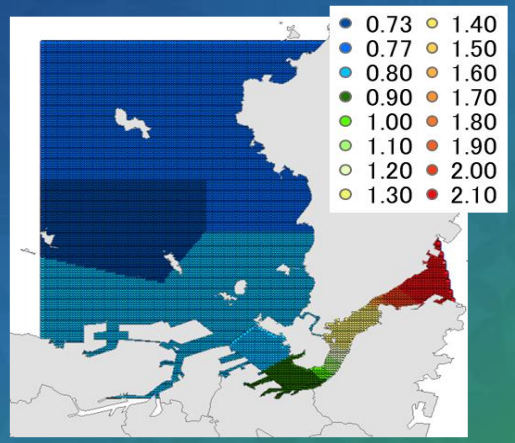

Z_0 [m]

Derived from the list of datum levels on the JCG website

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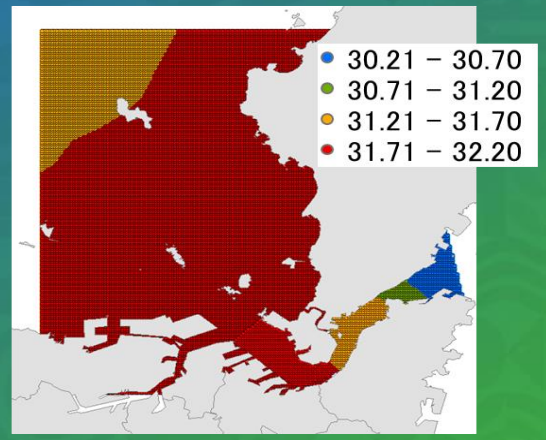


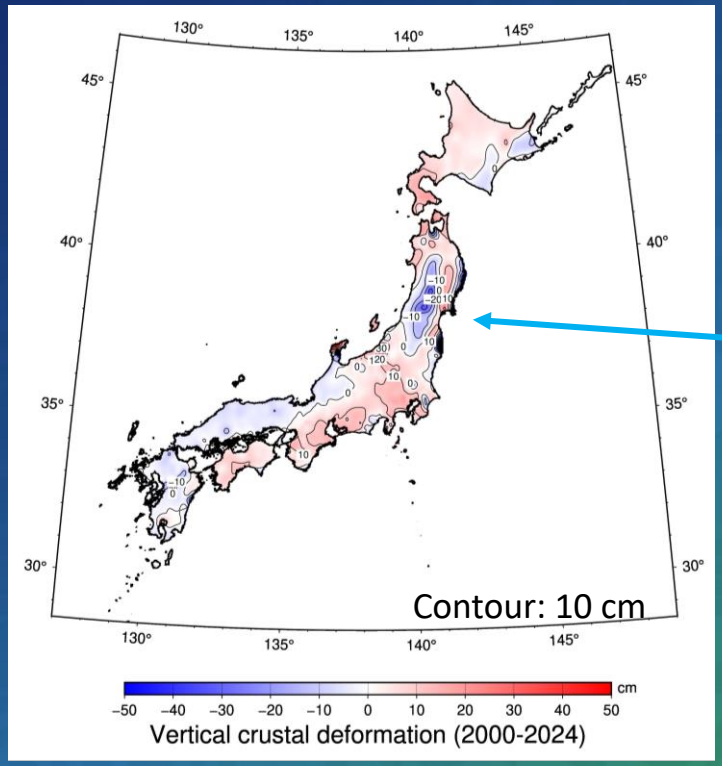
Chart datum model [m]

Gridded ellipsoidal heights of the chart datums

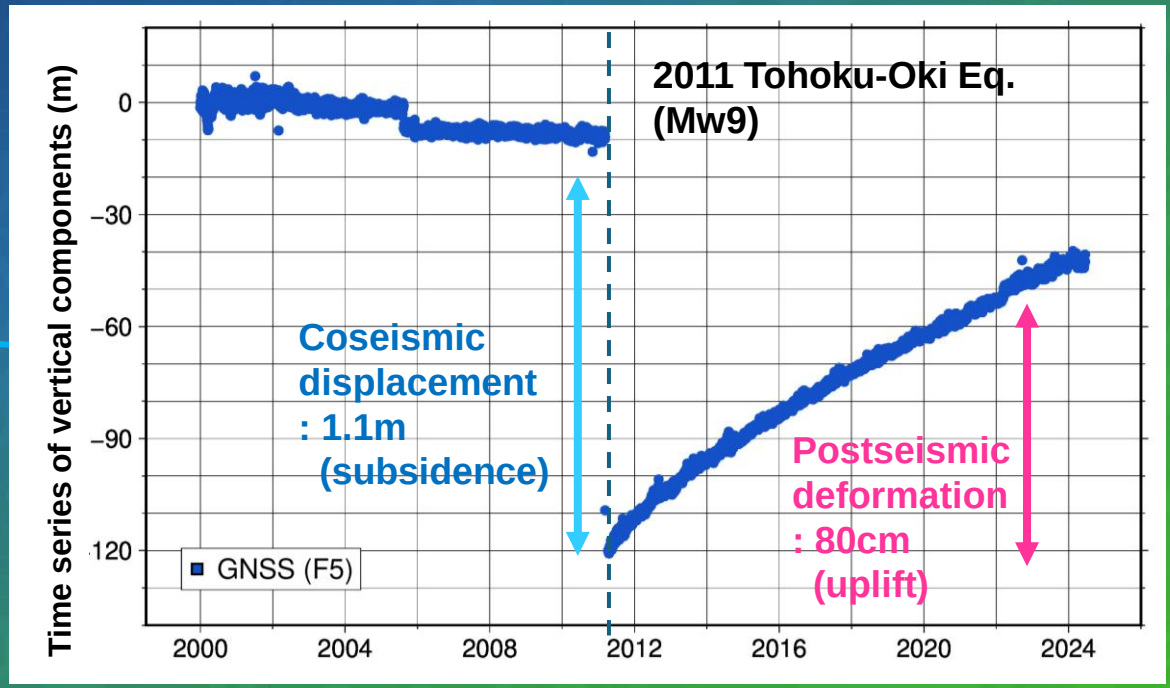
* MSL height: difference between ellipsoidal height of mean sea level and geoid model
Z_0 : height from Chart Datum to Mean Sea Level (MSL)

Challenges on Height System in Japan: Land

- Cumulative crustal deformation along coasts
  - ✓ Vertical crustal deformation continues long-term especially after trench-type megaquakes (**80cm uplift in 13 years** after the Tohoku-Oki earthquake)



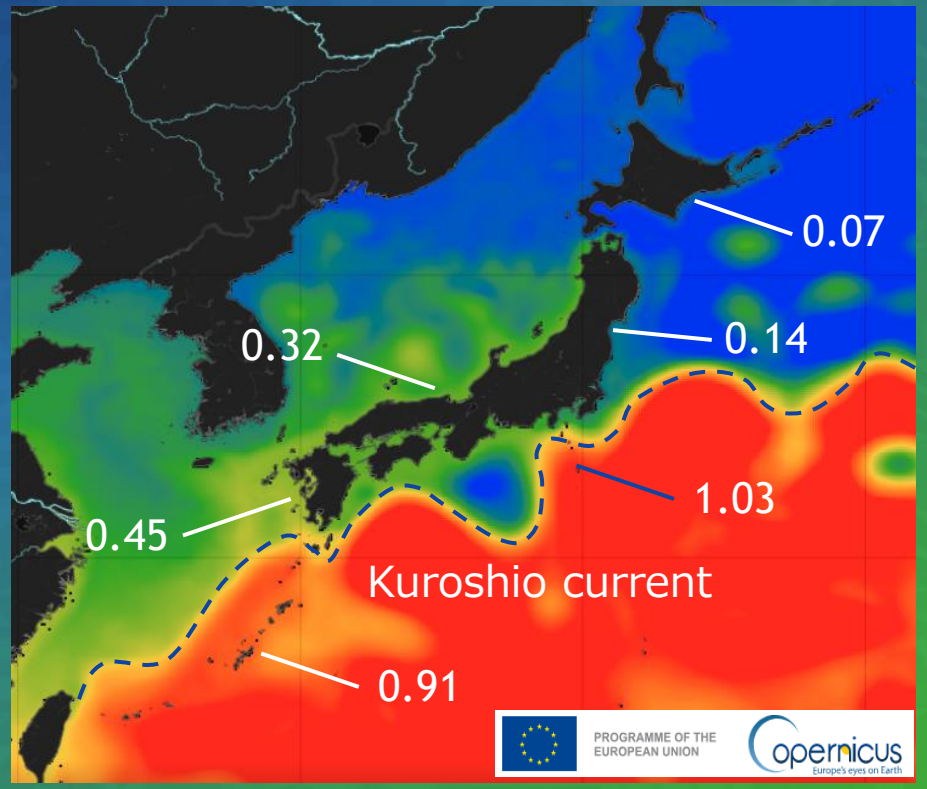
Cumulative vertical crustal deformation from 2000 to 2024

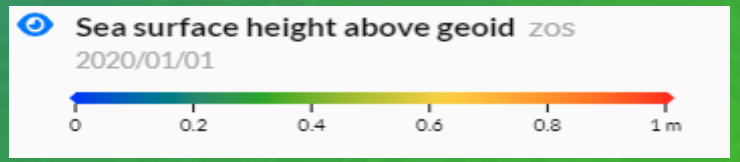


Vertical crustal deformation at GNSS site in Tohoku area (Oshika)

Challenges on Height System in Japan: Marine

- The difficulties in calculating MSL height in Japan
  - ✓ Kuroshio current is a western boundary current that passes near Japan.
  - ✓ Around Japan, MSL height varies greatly from place to place due to the effects of Kuroshio current and the topography.
  - ✓ Due to irregular Kuroshio current meander, **MSL height on the Pacific side varies greatly** from year to year.





Future Perspective and Challenges

- Introduction of new surveys both in land and marine
  - ✓ The both of new surveys use ellipsoidal heights from the same reference ellipsoid
  - ✓ Relationship between **heights in land and marine around Japan** will be clear and be able to **connect each other via the reference ellipsoid**
- Remaining challenges: spatiotemporal variations in related surface
  - ✓ Sea level change cannot be negligible because of **increasing sea level rise** & **cumulative large crustal deformation** especially after trench-type megaquakes
  - ✓ The **Kuroshio path variation** is causing unignorable complex changes in ocean surface around Japan
- Possible Solutions
  - ✓ Land: Dynamic height reference frame capable to track the crustal deformation
  - ✓ Marine: Continuous routine observation to track the changes in ocean surface