

**DEVELOPMENT OF A TSUNAMI FORECAST  
MODEL FOR  
HANALEI, HAWAI‘I, USA**

**Edison Gica**

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## **Table of Contents**

List of Tables.....	iii
List of Figures .....	iv
Abstract.....	2
1.0        Background and Objectives.....	2
2.0 Forecast Methodology .....	3
3. Model Development .....	4
3.1 Forecast area .....	5
3.2 Historical events and data .....	5
3.3 Model setup.....	6
4. Results and Discussion .....	7
4.1 Model validation .....	7
4.2 Model stability and reliability.....	8
4.3 Results of tested events .....	8
5. Summary and Conclusion .....	10
6.0 Acknowledgments .....	11
7.0 References .....	11
Appendix A .....	105
A1. Reference model *.in file for Hanalei, Hawai‘i .....	105
A2. Forecast model *.in file for Hanalei, Hawai‘i.....	105
Appendix C. Forecast Model tests in SIFT system. ....	157
C.1 Testing Procedure.....	157
C.2 Results .....	158

## List of Tables

Table 1. MOST setup parameters for reference and forecast models for Hanalei, Hawai‘i.....	12
Table 2. Historical events with recorded tsunami wave height at Hanalei, Hawai‘i.....	13
Table 3. Historical events simulated for Hanalei, Hawai‘i.....	14
Table 4. Synthetic mega-tsunamis tested for Hanalei, Hawai‘i.....	12
Table 5. Synthetic tsunamis with $M_w = 7.5$ and 0 tested for Hanalei, Hawai‘i.....	13
Table 6. Comparison of historical tsunami wave height with simulation at Hanalei, Hawai‘i.....	12
Table 7. Earthquake parameters for Aleutian-Alaska-Cascadia Subduction Zone unit sources.....	108
Table 8. Earthquake parameters for Central and South America Subduction Zone unit sources.....	115
Table 9. Earthquake parameters for East Philippines Subduction Zone unit sources. ....	127
Table 10. Earthquake parameters for Kamchatka-Kuril-Japan-Izu-Mariana-Yap Subduction Zone unit sources.....	130
Table 11. Earthquake parameters for Manus Oceanic Convergent Boundary Subduction Zone unit sources.....	142
Table 12. Earthquake parameters for Manus Oceanic Convergent Boundary Subduction Zone unit sources. ....	144
Table 13. Earthquake parameters for New Zealand-Kermadec-Tonga Subduction Zone unit sources. ....	146
Table 14. Earthquake parameters for New Zealand-Kermadec-Tonga Subduction Zone unit sources. ....	150
Table 15. Earthquake parameters for New Zealand-Puysegur Subduction Zone unit sources.....	153
Table 16. Earthquake parameters for New Zealand-Puysegur Subduction Zone unit sources.....	155
Table 17. Table of maximum and minimum amplitudes (cm) at the Hanalei, Hawai‘i warning point for synthetic and historical events tested using SIFT 3.2 and obtained during development. ....	159

## List of Figures

Figure 1. Location of Hanalei in the Hawaiian Islands. Hanalei is in the northern shores of the island of Kaua‘i (inset). .....	13
Figure 2. DEM grid provided by NGDC covering the ocean and northern half of Kauai. ....	13
Figure 3. Aerial view of Hanalei with labels indication the location of the Hanalei River, Waiali and Waipā streams and reef areas. ....	14
Figure 4. Contour plot of Hanalei area based on NGDC DEM. The first contour line on land is the 5 meter contour followed by a 10 meter contour up to 60 meters with 10 meters intervals. Similarly, the first contour on sea is the 5 meter depth followed by 10 meter depth intervals. Similarly, the first contour on sea is the 5 meter depth followed by a 10 meter depth and onwards with 10 meters interval. ....	14
Figure 5. Location of tide gauge station in Nawiliwili in relation to Hanalei. ....	15
Figure 6. Domain extent and elevation plot of forecast model for A-grid, B-grid and C-grid. Location of smaller grid in relation to the outer grid is indicated. ....	15
Figure 7. Domain extent and elevation plot of reference model for A-grid, B-grid and C-grid. Location of smaller grid in relation to the outer grid is indicated. ....	16
Figure 8. Location of Hanalei in relation to sixteen historical cases used to validate both forecast and reference model and as part of model stability and reliability tests. ....	17
Figure 9. Location of Hanalei in relation to synthetic events (42-Mw=9.3, 20-Mw=7.5 and 1-Mw = ~0) tested. ....	17
Figure 10. Maximum tsunami wave amplitude distribution of Unimak 1946 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures). .	18
Figure 11. Maximum tsunami wave amplitude distribution of Andreanov 1957 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures). ....	18
Figure 12. Maximum tsunami wave amplitude distribution of Chile 1960 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures). ....	19

Figure 13. Maximum tsunami wave amplitude distribution of East Kuril 1994 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures)..	19
Figure 14. Maximum tsunami wave amplitude distribution of Andreanov 1996 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures). .....	20
Figure 15. Maximum tsunami wave amplitude distribution of Peru 2001 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	20
Figure 16. Maximum tsunami wave amplitude distribution of Rat Island 2003 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures)..	21
Figure 17. Maximum tsunami wave amplitude distribution of Tonga 2006 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	21
Figure 18. Maximum tsunami wave amplitude distribution of Kuril 2006 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	22
Figure 19. Maximum tsunami wave amplitude distribution of Kuril 2007 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	22
Figure 20. Maximum tsunami wave amplitude distribution of Solomon 2007 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures)..	23
Figure 21. Maximum tsunami wave amplitude distribution of Peru 2007 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	23
Figure 22. Maximum tsunami wave amplitude distribution of Chile 2007 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	24
Figure 23. Maximum tsunami wave amplitude distribution of Samoa 2007 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	24
Figure 24. Maximum tsunami wave amplitude distribution of Chile 2010 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	25

Figure 25. Maximum tsunami wave amplitude distribution of 11 March 2011 Honshu tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures). ....	25
Figure 27. Tsunami wave amplitude distribution of Andreanov 1957 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Triangles are locations of historical tsunami wave height (NGDC) based on eyewitness accounts. Circle is the selected warning point location. ....	27
Figure 28. Tsunami wave amplitude distribution of Chile 1960 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Triangles are locations of historical tsunami wave height (NGDC) based on eyewitness accounts. Circle is the selected warning point location. ....	28
Figure 29. Tsunami wave amplitude distribution of East Kuril 1994 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location. ....	29
Figure 30. Tsunami wave amplitude distribution of Andreanov 1996 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location. ....	30
Figure 31. Tsunami wave amplitude distribution of Peru 2001 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location. ....	31
Figure 32. Tsunami wave amplitude distribution of Rat Island 2003 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location. ....	32
Figure 33. Tsunami wave amplitude distribution of Tonga 2006 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution	

(middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location. ....	33
Figure 34. Tsunami wave amplitude distribution of Kuril 2006 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Triangles are locations of historical tsunami wave height (NGDC) based on eyewitness accounts. Circle is the selected warning point location. ....	34
Figure 35. Tsunami wave amplitude distribution of Kuril 2007 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location. ....	35
Figure 36. Tsunami wave amplitude distribution of Solomon 2007 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location. ....	36
Figure 37. Tsunami wave amplitude distribution of Peru 2007 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location. ....	37
Figure 38. Tsunami wave amplitude distribution of Chile 2007 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location. ....	38
Figure 39. Tsunami wave amplitude distribution of Samoa 2009 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location. ....	39
Figure 40. Tsunami wave amplitude distribution of Chile 2010 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location. ....	40

Figure 41. Tsunami wave amplitude distribution of 11 March 2011 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location. ....	41
Figure 42. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami AC01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	42
Figure 43. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami AC11-20 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	42
Figure 44. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami AC21-30 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	43
Figure 45. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami AC31-40 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	43
Figure 46. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami AC41-50 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	44
Figure 47. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami AC51-60 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	44
Figure 48. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami AC56-65 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	45
Figure 49. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	45

Figure 50. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS11-20 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	46
Figure 51. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS21-30 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	46
Figure 52. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS31-40 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	47
Figure 53. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS41-50 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	47
Figure 54. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS51-60 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	48
Figure 55. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS61-70 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	48
Figure 56. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS71-80 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	49
Figure 57. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS81-90 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	49
Figure 58. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS91-100 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	50

Figure 59. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS101-110 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	50
Figure 60. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS106-115 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	51
Figure 61. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami EP01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	51
Figure 62. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami EP06-15 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	52
Figure 63. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	52
Figure 64. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI11-20 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	53
Figure 65. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI22-31 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	53
Figure 66. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI32-41 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	54
Figure 67. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI42-51 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	54

Figure 68. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI52-61 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	55
Figure 69. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI56-65 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	55
Figure 70. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI66-75 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	56
Figure 71. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami MO01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	56
Figure 72. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami MO06-15 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	57
Figure 73. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NG01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	57
Figure 74. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NG06-15 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	58
Figure 75. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NT01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	58
Figure 76. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NT11-20 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	59

Figure 77. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NT21-30 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	59
Figure 78. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NT30-39 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	60
Figure 79. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NV01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	60
Figure 80. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NV11-20 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	61
Figure 81. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NV28-37 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	61
Figure 82. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami RN01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	62
Figure 83. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami RN13-22AB for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).....	62
Figure 84. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event AC01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	63
Figure 85. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event AC11-20; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	64

Figure 86. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event AC21-30; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location..... 65

Figure 87. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event AC31-40; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location..... 66

Figure 88. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event AC41-50; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location..... 67

Figure 89. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event AC51-60; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location..... 68

Figure 90. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event AC56-65; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location..... 69

Figure 91. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location..... 70

Figure 92. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS11-20; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location..... 71

Figure 93. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS21-30; maximum wave amplitude (upper figures), minimum wave amplitude

distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	72
Figure 94. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS31-40; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	73
Figure 95. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS41-50; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	74
Figure 96. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS51-60; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	75
Figure 97. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS61-70; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	76
Figure 98. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS71-80; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	77
Figure 99. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event C81-90; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	78
Figure 100. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS91-100; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	79

Figure 101. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS101-110; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	80
Figure 102. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS106-115; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	81
Figure 103. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event EP01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	82
Figure 104. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event EP06-15; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	83
Figure 105. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	84
Figure 106. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI11-20; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	85
Figure 107. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI22-31; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	86
Figure 108. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI32-41; maximum wave amplitude (upper figures), minimum wave amplitude	

distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	87
Figure 109. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI42-51; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	88
Figure 110. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI52-61; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	89
Figure 111. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI56-65; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	90
Figure 112. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI66-75; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	91
Figure 113. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event MO01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	92
Figure 114. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event MO06-15; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	93
Figure 115. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NG01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	94

Figure 116. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NG06-15; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location..... 95

Figure 117. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NT01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location..... 96

Figure 118. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NT11-20; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location..... 97

Figure 119. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NT21-30; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location..... 98

Figure 120. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NT30-39; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location..... 99

Figure 121. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NV01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location..... 100

Figure 122. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NV11-20; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location..... 101

Figure 123. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NV28-37; maximum wave amplitude (upper figures), minimum wave amplitude

distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	102
Figure 124. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event RN01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	103
Figure 125. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event RN13-22; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.....	104
Figure 126. Aleutian-Alaska-Cascadia Subduction Zone unit sources .....	107
Figure 127. Central and South America Subduction Zone unit sources.....	114
Figure 128. East Philippines Subduction Zone unit sources.....	126
Figure 129. Kamchatka-Kuril-Japan-Izu-Mariana-Yap Subduction Zone unit sources.	129
Figure 130. Manus Oceanic Convergent Boundary Subduction Zone unit sources.....	141
Figure 131. New Guinea Subduction Zone unit sources. ....	143
Figure 132. New Zealand-Kermadec-Tonga Subduction Zone unit sources.....	145
Figure 133. New Britain-Solomons-Vanuatu Zone unit sources.....	149
Figure 134. New Zealand-Puyseger Zone unit sources. ....	152
Figure 135. Ryukyu-Kyushu-Nankai Zone unit sources. ....	154
Figure 136. Response of the Hanalei, Hawai‘i forecast model to synthetic scenario KISS 22-31 (alpha=30). aximum sea surface elevation for (a) A-grid, b) B-grid, c) C-grid. Sea surface elevation time series at the C-grid warning point (d). The lower time series plot is the result obtained during model development and is shown for comparison with test results. ....	160

Figure 137. Response of the Hanalei, Hawai‘i forecast model to synthetic scenario ACSZ 56-65 (alpha=30). Maximum sea surface elevation for (a) A-grid, b) B-grid, c) C-grid. Sea surface elevation time series at the C-grid warning point (d). ). The lower time series plot is the result obtained during model development and is shown for comparison with test results.....	161
Figure 138. Response of the Hanalei, Hawai‘i forecast model to synthetic scenario CSSZ 91-100 (alpha=30). Maximum sea surface elevation for (a) A-grid, b) B-grid, c) C-grid. Sea surface elevation time series at the C-grid warning point (d). The lower time series plot is the result obtained during model development and is shown for comparison with test results.....	162
Figure 139. Response of the Hanalei, Hawai‘i forecast model to synthetic scenario NTSZ 30-39 (alpha=30). Maximum sea surface elevation for (a) A-grid, b) B-grid, c) C-grid. Sea surface elevation time series at the C-grid warning point (d). ). The lower time series plot is the result obtained during model development and is shown for comparison with test results.....	163
Figure 140. Response of the Hanalei, Hawai‘i forecast model to the 2011 Tohoku tsunami. Maximum sea surface elevation for (a) A-grid, b) B-grid, c) C-grid. Sea surface elevation time series at the C-grid warning point (d). The lower time series plot is the result obtained during model development and is shown for comparison with test results.....	164

# **Development of a Tsunami Forecast Model for Hanalei, Hawai‘i, USA**

**Edison Gica**

## **Abstract**

The National Oceanic and Atmospheric Administration has developed a tsunami forecast model for Hanalei, Hawai‘i, as part of an effort to provide tsunami forecasts for United States coastal communities. Development, validation, and stability testing of the tsunami forecast model has been conducted to ensure model robustness and stability. The Hanalei, Hawai‘i tsunami forecast model employs the optimized version of the Method of Splitting Tsunami numerical code. The forecast model was validated with sixteen historical tsunamis and the stability and reliability was tested by simulating artificial tsunamis from different source regions. A total of 16 historical cases and 42 synthetic mega tsunami ( $M_w = 9.4$ ) events, 20  $M_w = 7.5$  and 1  $M_w = \sim 0$  were simulated and the forecast model was stable for 24 hours. The Hanalei, Hawai‘i forecast model can generate 4 hours of tsunami wave characteristics in approximately 4.6 minutes of CPU time.

## **1.0 Background and Objectives**

The National Oceanic and Atmospheric Administration (NOAA) Center for Tsunami Research (NCTR) at the NOAA Pacific Marine Environmental Laboratory (PMEL) has developed a tsunami forecasting capability for operational use by NOAA’s two Tsunami Warning Centers located in Hawai‘i and Alaska (Titov *et al.*, 2005). The system is designed to efficiently provide basin-wide warning of approaching tsunami waves accurately and quickly. The system, termed Short-term Inundation Forecast of Tsunamis (SIFT), combines real-time tsunami event data with numerical models to produce estimates of tsunami wave arrival times and amplitudes at a coastal community of interest. The SIFT system integrates several key components: deep-ocean observations of tsunamis in real time, a basin-wide pre-computed propagation database of water level and flow velocities based on potential seismic unit sources, an inversion algorithm to refine the tsunami source based on deep-ocean observations during an event, and high-resolution tsunami forecast models termed Forecast Models.

The town of Hanalei is located on the northern coast on the island of Kaua‘i (Figure 1). The coastal plain of Hanalei is very fertile and is nestled beneath green mountains. There are a few translations of the word ‘Hanalei’; ‘Crescent Bay’ because of the shape of its bay (Figure 1), ‘Lei Valley’ and ‘Wreath making’. Historically, Polynesians were the first to occupy Hanalei planting large amounts of taro, bananas, breadfruit, sweet potatoes, yams, coconuts and other food plants. In 1778, Captain James Cook was the first to establish western contact with the locals. By the first half of 1800s, it became the site of various agricultural endeavors. The area was a checkerboard of rice paddies from the late 1800s to early 1900s (Hawaiian Encyclopedia). Hanalei has earned a reputation for growing the sweetest taro in the state of Hawai‘i. Its main source of income is tourism and the estimated median household income is \$72,282 based on 2009 data (Hawai‘i State Info, CityData). Based on 2010 demographic profile, the population of Hanalei is

450 (US Census, [www.census.gov/popfinder](http://www.census.gov/popfinder), accessed 31 May 2012) which is a slight drop of 28 people from 2001 (Hawai‘i State Info. The entire area of Hanalei village covers only 2.1 square kilometers, making it the smallest village in Kauai, with a land area of 1.7 square kilometers and a water area of 0.4 square kilometers (Hawai‘i State Info).

The Tsunami Warning Centers selected Hanalei as part of the 75 tsunami forecast models that will be developed for the United States coastlines and territories. This report details the development of a tsunami forecast model for Hanalei, Hawai‘i. Development includes construction of a digital elevation model based on available bathymetric and topographic data, model validation with historic events, and stability tests of the model with a suite of mega tsunami events originating from subduction zones in the Pacific Ocean.

## **2.0 Forecast Methodology**

A high-resolution inundation model was used as the basis for development of a tsunami forecast model to operationally provide an estimate of wave arrival time, wave height, and inundation at Hanalei, Hawai‘i following tsunami generation. All tsunami forecast models are run in real time while a tsunami is propagating across the open ocean. The Hanalei, Hawai‘i model was designed and tested to perform under stringent time constraints given that time is generally the single limiting factor in saving lives and property. The goal of this work is to maximize the length of time that the community of Hanalei has to react to a tsunami threat by providing accurate information quickly to emergency managers and other officials responsible for the community and infrastructure.

The general tsunami forecast model, based on the Method of Splitting Tsunami (MOST), is used in the tsunami inundation and forecasting system to provide real-time tsunami forecasts at selected coastal communities. The model runs in minutes while employing high-resolution grids constructed by the National Geophysical Data Center. The Method of Splitting Tsunami (MOST) is a suite of numerical simulation codes capable of simulating three processes of tsunami evolution: earthquake, transoceanic propagation, and inundation of dry land. The MOST model has been extensively tested against a number of laboratory experiments and benchmarks (Synolakis *et al.*, 2008) and was successfully used for simulations of many historical tsunami events. The main objective of a forecast model is to provide an accurate, yet rapid, estimate of wave arrival time, wave height, and inundation in the minutes following a tsunami event. Titov and González (1997) describe the technical aspects of forecast model development, stability, testing, and robustness, and Tang *et al.*, 2009 provide detailed forecast methodology

A basin-wide database of pre-computed water elevations and flow velocities for unit sources covering worldwide subduction zones has been generated to expedite forecasts (Gica *et al.*, 2008). As the tsunami wave propagates across the ocean and successively reaches tsunameter observation sites, recorded sea level is ingested into the tsunami forecast application in near real-time and incorporated into an inversion algorithm to

produce an improved estimate of the tsunami source. A linear combination of the pre-computed database is then performed based on this tsunami source, now reflecting the transfer of energy to the fluid body, to produce synthetic boundary conditions of water elevation and flow velocities to initiate the forecast model computation.

Accurate forecasting of the tsunami impact on a coastal community largely relies on the accuracies of bathymetry and topography and the numerical computation. The high spatial and temporal grid resolution necessary for modeling accuracy poses a challenge in the run-time requirement for real-time forecasts. Each forecast model consists of three telescoped grids with increasing spatial resolution in the finest grid, and temporal resolution for simulation of wave inundation onto dry land. The forecast model utilizes the most recent bathymetry and topography available to reproduce the correct wave dynamics during the inundation computation. Forecast models, including the Hanalei, Kauai, Hawai'i model, are constructed for at-risk populous coastal communities in the Pacific and Atlantic Oceans. Previous and present development of forecast models in the Pacific (Titov *et al.*, 2005; Titov, 2009; Tang *et al.*, 2009; Wei *et al.*, 2008) have validated the accuracy and efficiency of each forecast model currently implemented in the real-time tsunami forecast system. Models are tested when the opportunity arises and are used for scientific research.

### **3. Model Development**

The general methodology for modeling at-risk coastal communities is to develop a set of three nested grids, referred to as A, B, and C-grids, each of which becomes successively finer in resolution as they telescope into the population and economic center of the community of interest. The offshore area is covered by the largest and lowest resolution A-grid while the near-shore details are resolved within the finest scale C-grid to the point that tide gauge observations recorded during historical tsunamis are resolved within expected accuracy limits. The procedure is to begin development with large spatial extent merged bathymetric topographic grids at high resolution, and then optimize these grids by sub-sampling to coarsen the resolution and reduce the overall grid dimensions to achieve a 4 hour simulation of modeled tsunami waves within the required time period of 10 min of wall-clock time. The basis for these grids is a high-resolution digital elevation model constructed by National Geophysical Data Center (NGDC) and NCTR using all available bathymetric, topographic, and shoreline data to reproduce the wave dynamics during the inundation computation for an at-risk community. For each community, data are compiled from a variety of sources to produce a digital elevation model referenced to Mean High Water in the vertical and to the World Geodetic System 1984 in the horizontal (NGDC). The author considers it to be an adequate representation of the local topography/bathymetry. As new digital elevation models become available, forecast models will be updated and report updates will be posted at [http://nctr.pmel.noaa.gov/forecast\\_reports/](http://nctr.pmel.noaa.gov/forecast_reports/). From these digital elevation models, a set of three high-resolution, 'reference' elevation grids are constructed for development of a high-resolution reference model from which an 'optimized' model is constructed to run in an operationally specified period of time. The operationally developed model is referred to as the optimized tsunami forecast model or forecast model for brevity.

Development of an optimized tsunami forecast model for Hanalei, Hawai‘i began with the spatial extent merged bathymetric/topographic grids shown in Figure 2. Grid dimension extension and additional information were updated as needed and appropriate. A significant portion of the modeled tsunami waves, 24 hrs of modeled tsunami time for Hanalei, Hawai‘i, pass through the model domain without appreciable signal degradation. Table 1 provides specific details of both reference model and forecast model grids, including extents and complete input parameter information for the model runs is provided in Appendix A.

### **3.1 Forecast area**

Hanalei is located in the northern shore of the island of Kaua‘i. It is situated in a crescent shaped bay, tucked between two emerald green mountains. The bay has Makahona Point on the west and Puu Poa Point on the east. Four separate watersheds; Hanalei, Wai‘oli, Waipā and Waikoko, flows into the Bay and its coastal plain spans across the lower regions of the four watershed (Hawaiian Encyclopedia). Two streams and one river flow thru Hanalei and empties into the bay; Waipā and Waiali streams are located on the west side and Hanalei River is located near Puu Poa Point located on the east side of the bay (Figure 3). The village is located in between Hanalei River and Waiali stream. There are two shopping centers in the village; Hanalei Center (located on the east near Hanalei River and Ching Young Village located west of Hanalei River (Figure 3). Hanalei Elementary School is on the west side of the village near Waiali stream as indicated in Figure 3.

The village of Hanalei covers only 2.1 square kilometers, making it the smallest village in Kaua‘i, with a land area of 1.7 square kilometers and a water area of 0.4 square kilometers (Hawai‘i State info). The village area is situated on an elevation of less than 5 meters. The 5 meter contour level is shown in Figure 4 (first contour line on land) and followed by a 10 meter contour increasing to 50 meters with 10 meters interval. There is also a similar low-level wide area on the Puu Poa Point side (east end of the bay). On the water side, coral reefs exist at both end of the bay, Puu Poa Reef on the east side and Waikoko Reef on the west side of the bay (Hawai‘i Travel Guide). This is evident in the contour plot of the ocean as shown in Figure 4. Similar to the contour interval on land; the first contour in the ocean is 5 meters followed by a 10 meter contour increasing to 50 meters with 10 meters intervals. With an elevation below 5 meters, the entire village is in danger of tsunami inundation. Location of tsunami sources that poses a threat is determined in Section 4.0.

### **3.2 Historical events and data**

The Hawaiian Islands is located such that they are along the path of any tsunamis generated in the Pacific Ocean. With active subduction zone in the Pacific Basin, the potential for tsunamigenic earthquakes is high (Nishenko 1991). The Hawaiian Islands had been hit by numerous tsunamis where a few (e.g. 1946 Unimak, 1952 Kamchatka, 1957 Aleutian Islands, 1960 Chile and 1975 Big Island tsunamis to name a few) have

caused millions of dollars in damage and human lives (Dr. G. Pararas-Carayannis). It is unfortunate that there are no historical tide gauge records at Hanalei since none has ever been installed. The closest tide gauge is located in Nawiliwili, Hawai‘i, located on the southeastern side of the island of Kauai (Figure 5) which is of no use for comparison or validation of the forecast model due to its location. For the development of Hanalei forecast model, the selected warning point is at 200.5016632°E, 22.2123146°N with a depth of 1.6 meters (Figures 6c and 7c).

Although there is no tide gauge at Hanalei, NGDC however has historical data of tsunami wave height based on eyewitness accounts (Table 2). A total of eight historical tsunamis are recorded in the database dating as far back as 1872. There are three locations of these recorded tsunami wave heights and all of these points are located on water. Plots of these locations are indicated in Figure 8. Hanalei was most affected by two tsunamis; the 1946 Aleutian and 1957 Andreanov. The 1946 Aleutian tsunami was so significant that it altered the course of Waipā stream, causing the collapse of the east end of Waikoko Bridge and washing away the carp that was stocked in the Lily Pond. Hanalei Bridge was damaged during the 1957 Andreanov tsunami and also displaced the Sanborn home along Weke Road approximately 10 feet from its foundation. What was interesting is that after being displaced only minor structural damage was found. The 1957 Andreanov event also disrupted the filming of ‘South Pacific’ which was being filmed in the north shores of Kauai (Hawaiian Encyclopedia).

### 3.3 Model setup

The high resolution Digital Elevation Model (DEM) for Hanalei, Hawai‘i was developed by NGDC (Carignan et al., 2011) with a grid resolution of 1/3 arc-seconds and coverage from 200.09°E to 200.91°E and 22.09°N to 22.66°N (Figure 2). The deepest water depth covered by the domain is 4,596 meters and the highest topography elevation is 1,421 meters. The DEM for the C-grid of the high resolution reference inundation model and the forecast model were extracted directly from the DEM developed by NGDC. While the DEM for the B-grid was extracted by combining the Hanalei 1/3 arc-second grid (Carignan et al., 2011) and Kauai 1/3 arc-second grid (Friday et al., 2012). The sources for the high resolution DEM were obtained from NGDC multibeam, NOS hydrographic surveys, USGS NED, Shoals LIDAR, FEMA LIDAR, NGDC Hanalei DEM, CCMA shoreline, JALBTCX/SHOALS surveys, NGDC multibeam, JALBTCX/PSC LIDAR, HI/FEMA LIDAR and NED 1/3 DEM. So as to be consistent with other inundation models developed for Hawai‘i region, the A-grid used for Hanalei was developed by Tang et al. (2010). Both high resolution reference inundation and forecast models consist of three nested grid where the outer most grid (Grid A) covers the deep ocean region so as to capture the tsunami characteristics as it propagates in the deep ocean while the inner most grid (Grid C) covers the shallower waters to capture the tsunami wave transformations. The extent of the A-grid covers the entire Hawaiian Islands to account for interaction of the tsunami waves due to the presence of the other islands while the B-grid covers the entire island of Kaua‘i to account for possible tsunami wrap-around effect. The extent of the C-grid was selected such that it covers the entire bay and taking into account the shallow water area offshore as shown in Figures 6c and 7c.

The coverage extent of the C-grid for both reference inundation model and forecast model are the same. Table 1 shows the details of the nested grid (Grids A, B and C) including the modeling parameters used. The plots of the nested grids are shown in Figures 6 and 7 for the forecast model and reference model, respectively. Although the digital elevation model used for the forecast and reference models are derived from the same source, the forecast model is an optimized version of the reference model designed to provide a quick tsunami forecast. The use of different grid resolution sometimes requires modification on the digital elevation model to make a stable and reliable run. Some areas in the C-grid were smoothed to eliminate instabilities and ringing effects. Since there is no tide gauge in Hanalei, a warning point was arbitrarily selected and is shown in Figures 6c and 7c which has a coordinate of 200.5016632°E, 22.2123146°N and a depth of 1.6 meter.

The forecast model, which is used for tsunami forecasting during an event, is an optimized version of the high resolution inundation model. It is designed so that it can quickly provide 4 hours of simulated tsunami wave characteristics which includes time series at the warning point. For Hanalei, Hawai‘i, the forecast model can simulate the tsunami wave characteristics in approximately 4.6 minutes (Table 1). The high resolution inundation model on the other hand takes about 1.9 hours to complete a simulated run of 4 hours. Both the high resolution inundation grid and forecast model were validated with historical events to check for accuracy.

## 4. Results and Discussion

The development of the reference and forecast model grids requires that it be validated with historical events and be tested for stability and reliability with synthetic scenarios. The synthetic scenarios tests uses a mega-event case with an  $M_w=9.3$ , an  $M_w=7.5$  and a no tsunami case with  $M_w=0$ . Validation with historical data is required to determine how well the model predicts the tsunami wave characteristics of actual events. The synthetic scenarios are to test whether both reference and forecast model grids will produce a stable simulation and locate possible instabilities in the selected grids. The synthetic mega-event scenarios can also be used as a preliminary risk analysis to determine which tsunami source region poses a threat to Hanalei, Hawai‘i. The tsunami time series at the selected tide gauge and maximum/minimum tsunami wave amplitude distribution are also compared between the reference and forecast model grids. This is to check whether the tsunami wave characteristics of the lower-resolution forecast model will not significantly deviate from the reference model grid.

### 4.1 Model validation

The development of the DEM for the high resolution reference inundation model and forecast model requires that it be validated to determine the accuracy of the simulated tsunami characteristics as it hits the coastal areas of Hanalei, Hawai‘i. Historically, lots of tsunamis had occurred in the Pacific Basin and most likely have impacted Hanalei,

Hawai‘i considering that it is located along the path of any tsunamis generated in the Pacific Basin. Unfortunately, no tide gauge has been established on the northern part of Kauai. The closest tide gauge is located in Nawiliwili Harbor, Hawai‘i which is located on the southeastern side of the island of Kauai (Figure 5). The wave characteristics at Kahului Harbor would be completely different from that at Hanalei, Hawai‘i thus cannot be used for comparison. However, historical records (NGDC) indicated tsunami wave height values (Table 2) at Hanalei, Hawai‘i for four historical events namely; 1 April 1946 Unimak, 9 Mar 1957 Andreeanov, 22 May 1960 Chile and 15 Nov 2006 Kuril tsunamis, will be used to validate the forecast and reference models. Other historical events are also simulated to determine how it affects the coastal areas of Hanalei (Table 3). The locations of these historical events relative to Hanalei are plotted in Figure 8.

#### **4.2 Model stability and reliability**

The development of the forecast model also requires that the model provides a reliable forecast and should be stable enough to simulate several hours of the tsunami event. A set of reliability and stability tests was conducted by simulating synthetic events (Table 4) emanating from different regions and using different earthquake magnitudes ( $M_w = 9.4, 7.5$  and  $0$ ). Since each tsunami event is unique, tests using different earthquake magnitudes and source location would indicate if the model grid developed will generate instabilities that need to be corrected. This set of tests is not exhaustive however, representative cases from select sources should be sufficient. A total of forty-two artificial mega-tsunamis ( $M_w=9.4$ ) were generated from twenty unit sources with a slip value of thirty meters for each unit source. Twenty cases of  $M_w=7.5$  use one unit source with a slip of one meter and one case of  $M_w=0$  is to tests the model for a no wave condition. The unit sources are from the propagation database developed at NCTR (Gica et al., 2008). Tests were conducted for a total of 24 hours of simulation. The list of sources used are indicated in Table 4 and 5 for the artificial mega-tsunamis and  $M_w=7.5$  and  $M_w=0$ , respectively. The maximum positive and negative tsunami amplitude at the warning point is also indicated in Table 4. The location of the synthetic events (Table 4) relative to Hanalei, Hawai‘i is shown in Figure 9.

#### **4.3 Results of tested events**

Results of the tested events (historical and synthetic) are shown by plotting the maximum/minimum tsunami wave amplitude distribution, inundation and tsunami time series. All the plots show both the forecast model and reference models. The simulated tsunami time series are recorded at the selected warning point (Figures 6c and 7c). Plots showing the maximum tsunami wave amplitude distribution for grids A, B and C are shown in Figures 10 to 25 and Figures 42 to 83 for historical events and synthetic mega-events (Table 4), respectively. Comparison of the maximum/minimum tsunami amplitude distribution and tsunami time series at C-grid level is shown in Figures 26 to 41 (historical events) and Figures 84 to 125 (synthetic mega-events, Table 4). These set of plots will show whether the coastal areas of Hanalei will be inundated or not and also the tsunami amplitude.

A total of 16 historical cases were simulated where 4 of the cases were used as validation of the Hanalei forecast and reference models. Since Hanalei does not have a tide gauge, the tsunami time series comparisons are done only between the forecast and reference model with exception for a few historical events where records of tsunami wave height are available (Table 2). The maximum tsunami wave amplitude distribution (Grids A, B and C) for historical events for forecast and reference models are shown in Figures 10 to 25. Comparison of maximum/minimum tsunami wave amplitude distribution and tsunami time series (at the warning point) at C-grid level between the forecast and reference models are shown in Figures 26 to 41. The first few tsunami waves match really well between the reference inundation model and forecast model for all historical cases. The succeeding waves though are sometimes higher for either the reference model or the forecast model. Similarly the phase has a good match for the first few waves and again some shift in the later wave for some cases. Finer distributions of the tsunami wave pattern are also seen in the reference models which are not present in the forecast model. Overall, the maximum/minimum tsunami wave amplitude distribution are similar between the forecast and reference models. Out of 16 historical cases only two cases affected Hanalei. Simulation of the Andreanov 1957 event produced extreme inundation affecting the significant portion of the village while Unimak 1496 case inundated areas along Hanalei River, Waiali stream and west of Waiali stream; this is due to the fact that the main energy was directed towards Hanalei.

From the historical cases simulated, National Geophysical Data Center (NGDC) has data of eyewitness accounts of tsunami wave height for four cases (Table 2) at two to three locations in Hanalei. Locations of these points are indicated in Figure 10. Table 6 compares the historical data and simulated tsunami wave height for both reference and forecast models. Overall the simulated results produce a much lower tsunami wave height as compared with historical data with the exception of November 13, 2006 Kuril tsunami where both the forecast and reference model have a very good agreement with 0.43 meters observed and 0.43 meters and 0.41 meters for the forecast and reference model, respectively. The average discrepancy with historical data for all four cases is 1.63 meters (forecast model) and 1.56 meters (reference model). A possible reason for this discrepancy is that the earthquake source is not well defined, especially for the older historical cases) or inaccuracy of the estimated tsunami wave height based on the eyewitness accounts.

The synthetic events simulated for the forecast model show that it is both stable and reliable for a twenty-four hours simulation. Although the mega-tsunami ( $M_w = 9.4$ , Table 4) tests are not exhaustive, the results can indicate which tsunami source regions would pose a threat to Hanalei, Hawai‘i. The maximum tsunami wave amplitude distribution for grids A, B and C are shown in Figures 42 to 83 for the forecast and reference models. Figures 84 to 125 compare the maximum/minimum tsunami wave amplitude distribution and time series (at selected warning point) at C-grid level between the forecast and reference model and would also indicate the extent of inundation.

Results of the inundation extent between the forecast model and reference model for the synthetic mega-tsunami are comparable to each other. Although there are a few cases

where the forecast model shows a bit more inundation as compared to the reference model, cases like AC01-10 (Figure 84), CS01-10 (Figure 91), CS51-60 (Figure 96), CS61-70 (Figure 97), KI52-61 (Figure 110), KI56-65 (Figure 111), NT11-20 (Figure 117), NT21-30 (Figure 119), NT30-39 (Figure 120), RN01-10 (Figure 124) and RN13-22 (Figure 125). This could be attributed to the sub-sampling of the grid whereby a higher elevation point might have been excluded from the sampling interval causing the area to be lower/flatter than it is supposed to be. Out of 42 synthetic mega-tsunami ( $Mw=9.4$ , Table 4) simulated only seven of the cases (CS11-20, CS21-30, CS31-40, CS41-50, NG01-10, NT01-10, NV01-10) did not affect Hanalei indicating that the main tsunami energy is directed away. Twelve sources generated minor inundation restricted along the river and streams. Fifteen cases produced significant inundation that affects the areas along Hanalei River (on the east) and Waiali and Waipa streams (on the west). In some cases, more than half of the town area is inundated (Figures 84, 87, 88, 89, 90, 91, 101, 102, 103, 104, 106, 107, 109, 111, 119 and 124). Tsunami sources that have extreme coastal impact emanates from eight sources, AC11-20, AC21-30, KI01-10, KI32-41, KI66-75, MO01-10, NT30-39 and NV28-37. The inundation extent for these tsunami sources either covers the entire or almost all of the low-land area of Hanalei (Figures 85, 86, 105, 108, 112, 113, 120 and 123).

## 5. Summary and Conclusion

A set of reference and forecast inundation models has been prepared for Hanalei, Hawai‘i. During the development of the forecast model, instabilities occurred in the C-grid due to its complex bathymetry. The locations that caused instability were corrected by smoothing a cluster of nodes. Although there were corrections made to the DEM both models were found to be reliable and the comparison of the maximum/minimum tsunami wave amplitude distribution and the tsunami time series at the warning point were relatively good.

Reliability of the reference and forecast inundation models were validated with four historical events. The National Geophysical Data Center has records of historical wave height based on eyewitness accounts due to tsunami in Hanalei which are due to 1 April 1946 Unimak Island, 9 March 1957 Andreanov, 22 May 1960 Chilean and 15 November 2007 Kuril tsunamis. Comparison with the historical records show that the simulated tsunami wave height was on average 1.63 meters (forecast model) and 1.56 meters (reference model) less than the record with the exception of the 2006 Kuril tsunami where the comparison is very good. The discrepancy could indicate that either the source used by NCTR is still not well-defined (especially for the older events) or possible inaccuracy in the historical data in NGDC considering that the information is based on eye-witness account and that the points indicated are all on water. Other historical events were also simulated to determine how it could have affected the coastal area.

The stability tests showed that both the forecast and reference models are stable for a 24-hour simulation for both historical cases and synthetic sources (Tables 4 and 5) with different earthquake magnitudes (i.e.  $Mw = 9.4$ , 7.5, and 0) emanating from different

source regions. A total of 42 Mw =9.4, 20 Mw =7.5 and 1 Mw=0 were simulated. The mega-tsunami events not only checks the stability of the forecast model, it can also provide information on which source region is Hanalei, Hawai‘i more susceptible to tsunamis. From the limited test of synthetic scenarios conducted, 7 source scenarios produce no inundation along the coast with 10 producing minor inundation. Significant inundation was from 17 source scenarios and 8 extreme cases that completely or almost completely inundated all the low-land areas of the coastal town.

Since the main objective of developing the Hanalei, Hawai‘i forecast model is for the tsunami forecast, the DEM has been optimized to simulate 4 hours of tsunami wave characteristics in approximately 4.6 minutes. As presented in this report, the Hanalei, Hawai‘i forecast model should be able to provide a reliable forecast during an event and is stable for a 24 hours simulation. Other than being used as a forecast model in real-time events, the developed grids can also be used for hazard assessment to assist the local community in developing an evacuation plan.

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## **7.0 References**

Carignan, K.S., L.A. Taylor, B.W. Eakins, D.Z. Friday, P.R. Grothe, E. Lim and M. Love (2011): Digital Elevation Model of Hanalei, Hawai‘i: Procedures, Data Sources and Analysis, National Geophysical Data Center, Boulder, Colorado, USA.

City Data, [www.city-data.com/city/Hanalei-Hawaii.html](http://www.city-data.com/city/Hanalei-Hawaii.html) (accessed 31 May 2012).

Friday, D.Z., L.A. Taylor, B.W. Eakins, K.S. Carignan, M.R. Love and P.R. Grothe (2012): Digital Elevation Model of Kauai, Hawai‘i: Procedures, Data Sources and Analysis, National Geophysical Data Center, Boulder, Colorado, USA.

Gica, Edison, M.C. Spillane, V.V. Titov, C.D. Chamberlin and J.C. Newman (2008): Development of the forecast propagation database for NOAA’s Short-term Inundation Forecast for Tsunamis (SIFT), NOAA Tech. Memo OAR PMEL139, NOAA/Pacific Marine Environmental Laboratory, Seattle, WA, 89pp.

Hawaiian Encyclopedia, <http://www.hawaiianencyclopedia.com/hanalei-history-part-5.asp> (accessed 7 June 2012).

Hawai‘i State Info, <http://www.hawaiistateinfo.com/hanalei.php> (accessed 31 May 2012).

Hawai‘i Travel Guide, [www.to-hawaii.com](http://www.to-hawaii.com) (accessed 31 May 2012).

Nishenko, Stuart P. (1991): Circum-Pacific Seismic Potential: 1989-1999, Pure and Applied Geophysics, Vol. 135, No. 2, pp 169-259.

National Geodetic and Data Center  
<http://ngdc.noaa.gov/mgg/inundation/tsunami/inundation.html>, accessed 1 June 2011.

Pararas-Caryannis, George, <http://www.drgeorgepc.com/> (accessed 7 June 2012).

Synolakis, C.E., E.N. Bernard, V.V. Titov, U. Kânoğlu and F.I. González (2008): Validation and verification of tsunami numerical models. *Pure and Applied Geophysics* 165(11-12), 2197-2228.

Tang, L., V.V. Titov, and C.D. Chamberlin (2009): Development, testing, and applications of site-specific tsunami inundation models for real-time forecasting. *J. Geophys. Res.*, 6, doi: 10.1029/2009JC005476, in press.

Tang, L., Chamberlin, C.D. and Titov, V.V. (2010): A tsunami forecast model for Hilo, Hawai‘i, NOAA OAR Special Report, PMEL Tsunami Forecast Series: Vol. 1, 94 pp.

Titov, V.V. and F.I. Gonzalez (1997): Implementation and testing of Method of Splitting Tsunami (MOST) model. NOAA Tech. Memo. ERL PMEL-112 (PB98-122773), NOAA/Pacific Marine Environmental Laboratory, Seattle, WA, 11pp.

Titov, V.V., F.I. Gonzalez, E.N. Bernard, M.C. Eble, H.O. Mofjeld, J.C. Newman and A.J. Venturato (2005): Real-time tsunami forecasting: Challenges and solutions. *Natural Hazards*, 35, 41-58.

Titov, V.V. (2009): Tsunami forecasting. In *The Sea*, Vol. 15, Chapter 12, Harvard University Press, Cambridge, MA, and London, England, 371–400.

US Census Bureau, <http://www.census.gov/popfinder> (accessed 31 May 2012).

Wei, Y., E. Bernard, L. Tang, R. Weiss, V. Titov, C. Moore, M. Spillane, M. Hopkins, and U. Kânoğlu (2008): Real-time experimental forecast of the Peruvian tsunami of August 2007 for U.S. coastlines. *Geophys. Res. Lett.*, 35, L04609, doi: 10.1029/2007GL032250.

Table 1. MOST setup parameters for reference and forecast models for Hanalei, Hawai‘i.

		Reference Model				Forecast Model				
Grid	Region	Coverage	Cell	nx	Time	Coverage	Cell	nx	Time	
		Lat. [°N]	Size	x	Step	Lat. [°N]	Size	x	Step	
Grid	Region	Lon. [°W]	[“]	ny	[sec]	Lon. [°W]	[“]	ny	[sec]	
		18.0083-22.9983 199.0000-205.9799	36	699 x 500	3.0	18.0317-22.9983 199.0000-205.9667	120	210 x 150	12.0	
B	Kauai	21.7000-22.5000 200.1017-200.9017	6	481 x 481	0.6	21.7000-22.5000 200.10167-200.9017	36	161 x 161	2.4	
		22.1917-22.2444 200.4750-200.5110	1/3	390 x 569	0.3	22.1917-22.2444 2000.4750-200.5109	2/3	195 x 285	0.6	
Minimum offshore depth [m]		1.0				1.0				
Water depth for dry land [m]		0.1				0.1				
Friction coefficient [n2]		0.000063				0.00063				
CPU time for 4-hr simulation		1.9 hours				4.6 minutes				

Computations were performed on a dual Hex-core Intel Xeon E5670 processor at 2.936 GHz each 12M cache, 32 GB Memory, Dell PowerEdge R510.

Table 2. Historical events with recorded tsunami wave height at Hanalei, Hawai‘i.

Event	Earthquake Date Time (UTC)	Lat. (°)	Lon. (°)	Seismic Moment Magnitude (Mw)	Tsunami wave height Location <sup>1</sup>		
					Lat. (°)	Lon. (°)	Maximum Water height (m) <sup>1</sup>
1946 Unimak	1946-04-01 12:28:56	52.750N	163.500W	8.5 <sup>2</sup>	22.210N	159.500W	5.80
					22.215N	159.521W	3.00
					22.216N	159.501W	2.70
					22.216N	159.501W	3.70
					22.216	159.501W	4.30
1957 Andreanov <sup>3</sup>	1957-03-09 14:22:31.9	38.290N	175.39W	8.6 <sup>3</sup>	22.215N	159.521W	5.80
					22.216N	159.501W	5.20
					22.216N	159.501W	5.80
1960 Chile <sup>3</sup>	1960-05-22 19:11:17	38.290S	73.05W	9.5 <sup>4</sup>	22.215N	159.521W	1.70
					22.216N	159.501W	2.70
					22.216N	159.501W	2.30
					22.216N	159.501W	2.60
2006 Kuril Islands	2006-11-15 11:14:16	46.607N	153.230E	8.3 <sup>5</sup>	22.216N	159.501W	0.43

<sup>1</sup> National Geophysical Data Center (NGDC)

<sup>2</sup> López and Okal (2006)

<sup>3</sup> United States Geological Survey (USGS)

<sup>4</sup> Kanamori and Cipar (1974)

<sup>5</sup> Centroid Moment Tensor

Table 3. Historical events simulated for Hanalei, Hawai‘i.

Event	Earthquake Date Time (UTC)	Lat. (°)	Lon. (°)	Subduction Zone	Seismic Moment Magnitude (Mw)	Tsunami Magnitude <sup>1</sup>	Model Tsunami Source
1946 Unimak	1946-04-01 12:28:56	52.75N	163.50W	Aleutian-Alaska-Cascadia (ACSZ)	8.5 <sup>2</sup>	8.5	7.5 x b23 + 19.7 x b24 + 3.7 x b25
1957 Andreanov	1957-03-09 14:22:31	51.56N	175.39W	Aleutian-Alaska-Cascadia (ACSZ)	8.6 <sup>3</sup>	8.7	31.4 x a15 + 10.6 x a16 + 12.2 x a17
1960 Chile	1960-05-22 19:11:14	38.29S	73.050W	Central-South America (CSSZ)	9.5 <sup>4</sup>		Kanamori & Cipar (1974)
1994 East Kuril	1994-10-04 13:22:58	43.73N	147.321E	Kamchatka-Kuril-Japan-Izu-Marian-Yap (KISZ)	8.3 <sup>5</sup>	8.1	9.0 x a20
1996 Andreanov	1996-06-10 04:03:35	51.56N	175.39W	Aleutian-Alaska-Cascadia (ACSZ)	7.9 <sup>5</sup>	7.8	2.40 x a15 + 0.80 x b16
2001 Peru	2001-06-23 20:33:14	16.265S	73.641W	Central-South America (CSSZ)	8.4 <sup>5</sup>	8.2	5.7 x a15 + 2.9 x b16 + 1.98 x a16
2003 Rat Island	2003-11-17 06:43:31.0	51.14N	177.86E	Aleutian-Alaska-Cascadia (ACSZ)	7.7 <sup>5</sup>	7.8	2.81 x b11
2006 Tonga	2006-05-03 15:27:03.7	20.39S	173.47W	New Zealand-Kermadec-Tonga (NTSZ)	8.0 <sup>5</sup>	8.0	4 x a12 + 0.5 x b12 + 2 x a13 + 1.5 x b13
2006 Kuril	2006-11-15 11:15:08.0	46.71N	154.33E	Kamchatka-Kuril-Japan-Izu-Marian-Yap (KISZ)	8.3 <sup>5</sup>	8.1	4 x a12 + 0.5 x b12 + 2 x a13 + 1.5 x b13

Table 3. continued

2007 Kuril	2007-01-13 04:23:48.1	46.17N	154.80E	Kamchatka-Kuril-Japan-Izu-Marian-Yap (KISZ)	$8.1^5$	7.9	-3.64 x b13
2007 Solomon	2007-04-01 20:39:56	8.481S	156.978E	New Britain-Solomons-Vanuatu (NVSZ)	$8.1^3$	8.2	12.0 x b10
2007 Peru	2007-08-15 23:40:57	13.345 S	76.509W	Central-South America (CSSZ)	$8.0^5$	8.1	0.9 x a61 + 1.25*b61+ 5.6 x a62 + 6.97 x b62 + 3.5 x z62
2007 Chile	2007-11-14 15:40:50	22.204 S	69.869W	Central-South America (CSSZ)	$7.7^3$	7.6	1.65 x Z73
2009 Samoa	2009-09-29 17:48:10	15.509 S	172.034 W	New Zealand-Kermadec-Tonga (NTSZ)	$8.1^5$	8.1	3.96 x a34 + 3.96 x b34
2010 Chile	2010-02-27 06:35:15.4	35.950 S	73.150W	Central-South America (CSSZ)	$8.8^5$	8.8	7.78 x a87 + 12.32 x a88 + 20.04 x z88 + 10.6 x a91 + 19.93 x z92
2011 Honshu	2011-03-11 05:46:00	38.322 N	142.369E	Kamchatka-Kuril-Japan-Izu-Marian-Yap (KISZ)	$9.0^5$	8.8	4.66 x b24 + 12.23 x b25 + 26.31 x a26 + 21.27 x b26 + 22.75 x a27 + 4.98 x b27

<sup>1</sup>Preliminary source – derived from source and deep-ocean observations <sup>2</sup>López and Okal (2006) <sup>3</sup>United States Geological Survey (USGS)<sup>4</sup>Kanamori and Cipar (1974) <sup>5</sup>Centroid Moment Tensor

Table 4. Synthetic mega-tsunamis tested for Hanalei, Hawai‘i.

Scenario Name	Subduction Zone	Tsunami Source (multiplied by 30)	Tsunami amplitude at Warning point (24hours simulation, forecast model)	
			Maximum positive (cm)	Maximum negative (cm)
ACSZ 01-10	Aleutian-Alaska-Cascadia	A01-10, B01-10	228.66	160.00
ACSZ 11-20	Aleutian-Alaska-Cascadia	A11-20, B11-20	849.31	160.00
ACSZ 21-30	Aleutian-Alaska-Cascadia	A21-30, B21-30	610.92	160.00
ACSZ 31-40	Aleutian-Alaska-Cascadia	A31-40, B31-40	279.53	160.00
ACSZ 41-50	Aleutian-Alaska-Cascadia	A41-50, B41-50	377.44	160.00
ACSZ 51-60	Aleutian-Alaska-Cascadia	A51-60, B51-60	331.31	160.00
ACSZ 56-65	Aleutian-Alaska-Cascadia	A56-65, B56-65	398.49	160.00
CSSZ 01-10	Central-South America	A01-10, B01-10	134.53	147.87
CSSZ 11-20	Central-South America	A11-20, B11-20	44.59	52.02
CSSZ 21-30	Central-South America	A21-30, B21-30	44.59	52.02
CSSZ 31-40	Central-South America	A31-40, B31-40	68.28	80.71
CSSZ 41-50	Central-South America	A41-50, B41-50	82.52	94.27
CSSZ 51-60	Central-South America	A51-60, B51-60	180.54	160.00
CSSZ 61-70	Central-South America	A61-70, B61-70	206.97	160.00
CSSZ 71-80	Central-South America	A71-80, B71-80	136.92	160.00
CSSZ 81-90	Central-South America	A81-90, B81-90	128.37	160.00
CSSZ 91-100	Central-South America	A91-100, B91-100	161.73	160.00
CSSZ 101-110	Central-South America	A101-110, B101-110	302.15	160.00
CSSZ 106-115	Central-South America	A106-115, B106-115	322.57	160.00
EPSZ 01-10	East Philippines	A01-10, B01-10	327.96	160.00
EPSZ 06-15	East Philippines	A06-15, B06-15	338.85	160.00
KISZ 01-10	Kamchatka-Yap-Mariana-Izu-Bonin	A01-10, B01-10	576.78	160.00
KISZ 11-20	Kamchatka-Yap-Mariana-Izu-Bonin	A11-20, B11-20	295.44	160.00

Table 4. continued.

KISZ 22-31	Kamchatka-Yap-Mariana-Izu-Bonin	A22-31, B22-31	342.27	160.00
KISZ 32-41	Kamchatka-Yap-Mariana-Izu-Bonin	A32-41, B32-41	459.03	160.00
KISZ42-51	Kamchatka-Yap-Mariana-Izu-Bonin	A42-52, B42-51	364.36	160.00
KISZ52-61	Kamchatka-Yap-Mariana-Izu-Bonin	A52-61, B52-61	275.32	160.00

Table 5. Synthetic tsunamis with Mw = 7.5 and 0 tested for Hanalei, Hawai‘i.

Scenario Name	Mw	Subduction Zone	Tsunami Source
ACSZ 9	7.5	Aleutian-Alaska-Cascadia	B9
ACSZ 18	7.5	Aleutian-Alaska-Cascadia	B18
ACSZ 30	7.5	Aleutian-Alaska-Cascadia	B18
ACSZ 50	7.5	Aleutian-Alaska-Cascadia	B50
ACSZ 65	7.5	Aleutian-Alaska-Cascadia	B65
CSSZ 2	7.5	Central-South America	B2
CSSZ 22	7.5	Central-South America	B22
CSSZ 49	7.5	Central-South America	B49
CSSZ 59	7.5	Central-South America	B59
CSSZ 84	7.5 and ~0	Central-South America	B84
EPSZ 10	7.5	East Philippines	B10
KISZ 8	7.5	Kamchatka-Yap-Mariana-Izu-Bonin	B8
KISZ 15	7.5	Kamchatka-Yap-Mariana-Izu-Bonin	B15
KISZ 27	7.5	Kamchatka-Yap-Mariana-Izu-Bonin	B27
KISZ 53	7.5	Kamchatka-Yap-Mariana-Izu-Bonin	B53
MOSZ 9	7.5	Manus OCB	B9
NTSZ 19	7.5	New Zealand-Kermadec-Tonga	B19
NTSZ 36	7.5	New Zealand-Kermadec-Tonga	B36
NVSZ 23	7.5	New Britain-Solomons-Vanuatu	B23
RNSZ 11	7.5	Ryukus-Kyushu-Nankai	B11

Table 6. Comparison of historical tsunami wave height with simulation at Hanalei, Hawai‘i.

Event	Earthquake Date Time (UTC)	Tsunami wave height Location <sup>1</sup>				
		Lat. (°)	Lon. (°)	Wave height (m) <sup>1</sup>	Simulated wave height (m)	
					Forecast Model	Reference Model
1946 Unimak	1946-04-01 12:28:56	22.210N	159.500W	5.80	2.84	3.09
		22.215N	159.521W	3.00	1.37	1.60
		22.216N	159.501W	2.70	2.57	2.84
		22.216N	159.501W	3.70	2.57	2.84
		22.216	159.501W	4.30	2.57	2.84
1957 Andreanov	1957-03-09 14:22:31.9	22.215N	159.521W	5.80	2.26	2.32
		22.216N	159.501W	5.20	3.55	3.65
		22.216N	159.501W	5.80	3.55	3.65
1960 Chile	1960-05-22 19:11:17	22.215N	159.521W	1.70	0.55	0.60
		22.216N	159.501W	2.70	0.59	0.73
		22.216N	159.501W	2.30	0.59	0.73
		22.216N	159.501W	2.60	0.59	0.73
2006 Kuril Islands	2006-11-15 11:14:16	22.216N	159.501W	0.43	0.43	0.41

<sup>1</sup>National Geophysical Data Center (NGDC)

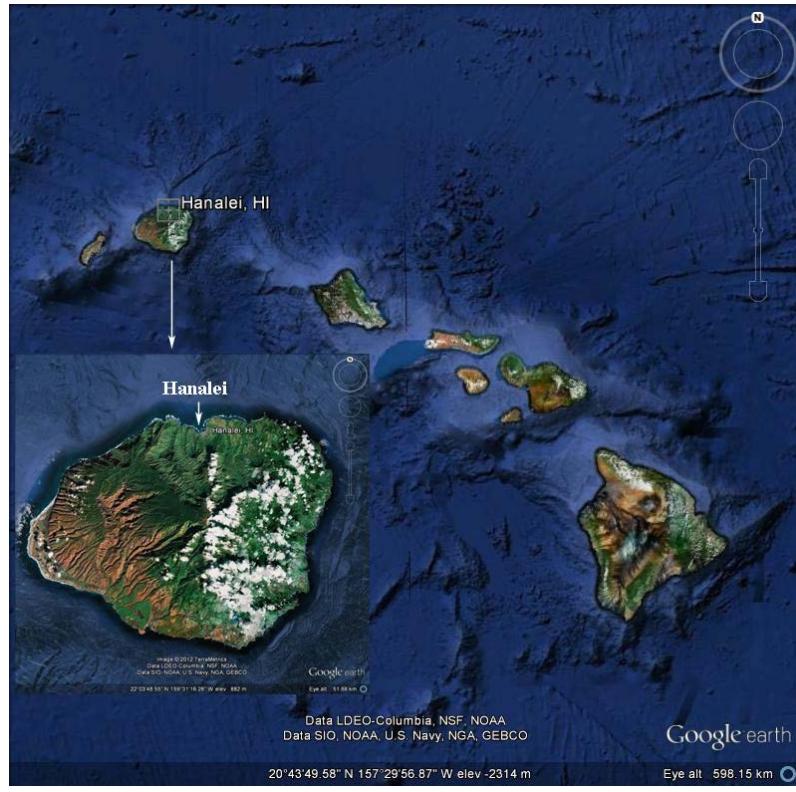


Figure 1. Location of Hanalei in the Hawaiian Islands. Hanalei is in the northern shores of the island of Kaua‘i (inset).

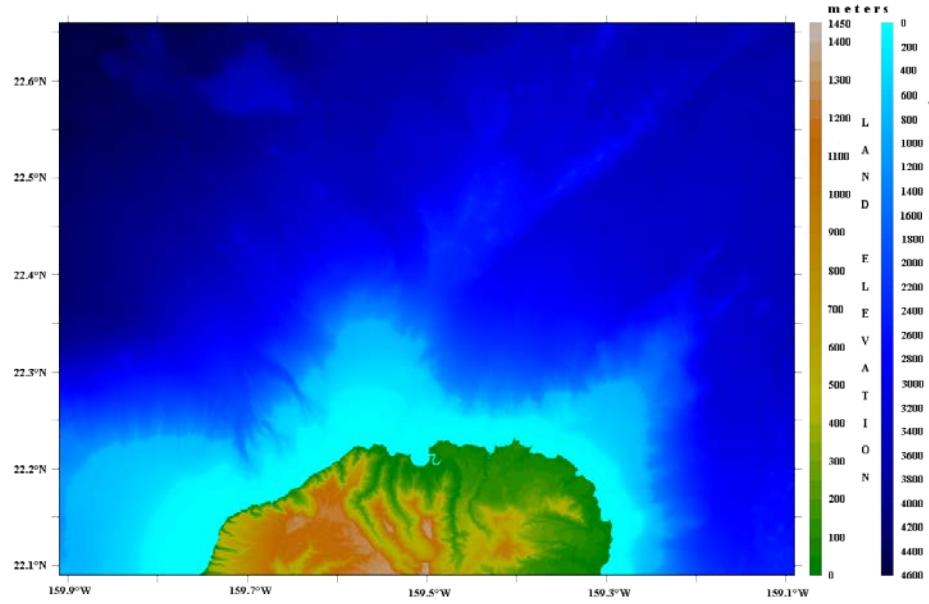


Figure 2. DEM grid provided by NGDC covering the ocean and northern half of Kauai.



Figure 3. Aerial view of Hanalei with labels indication the location of the Hanalei River, Waiali and Waipā streams and reef areas.

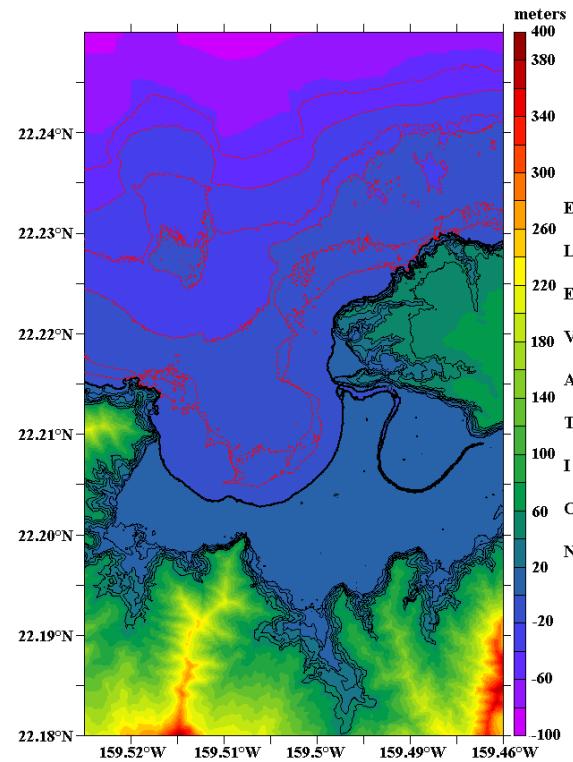


Figure 4. Contour plot of Hanalei area based on NGDC DEM. The first contour line on land is the 5 meter contour followed by a 10 meter contour up to 60 meters with 10 meters intervals. Similarly, the first contour on sea is the 5 meter depth followed by 10 meter depth intervals. Similarly, the first contour on sea is the 5 meter depth followed by a 10 meter depth and onwards with 10 meters interval.

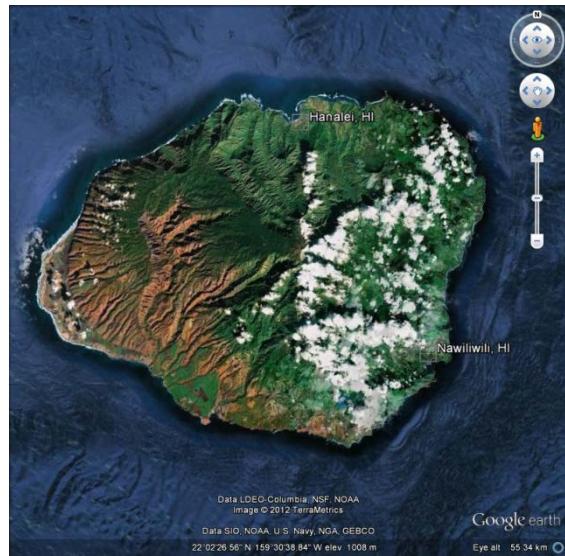


Figure 5. Location of tide gauge station in Nawiliwili in relation to Hanalei.

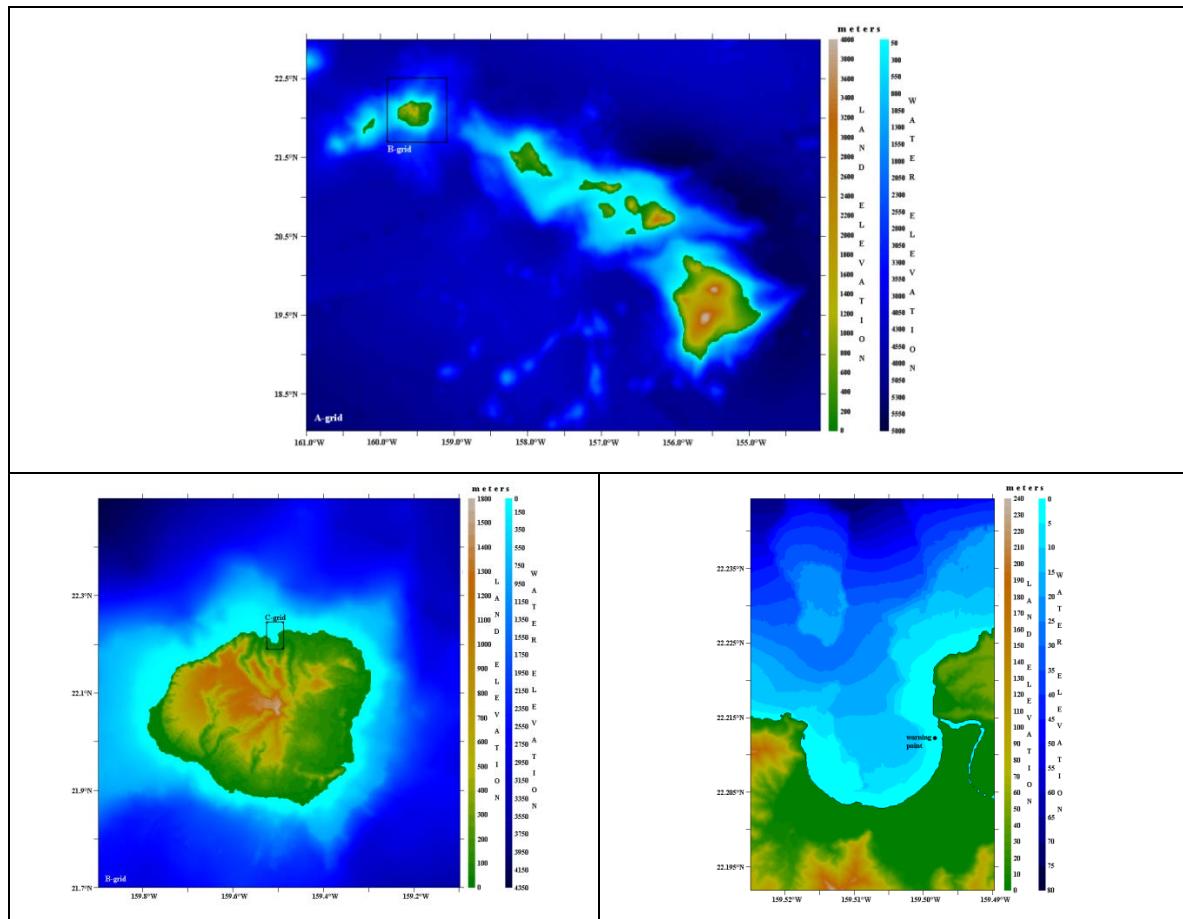


Figure 6. Domain extent and elevation plot of forecast model for A-grid, B-grid and C-grid. Location of smaller grid in relation to the outer grid is indicated.

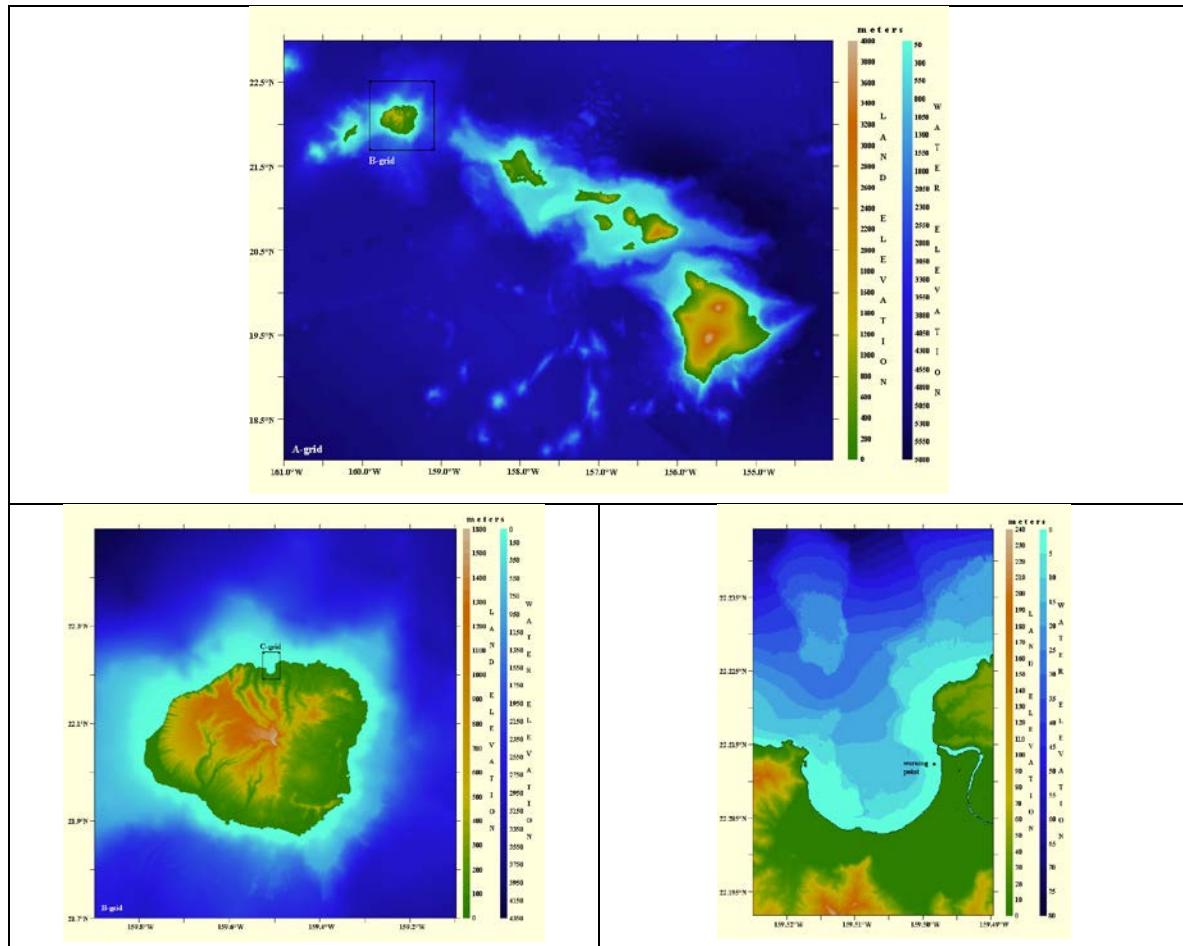


Figure 7. Domain extent and elevation plot of reference model for A-grid, B-grid and C-grid. Location of smaller grid in relation to the outer grid is indicated.

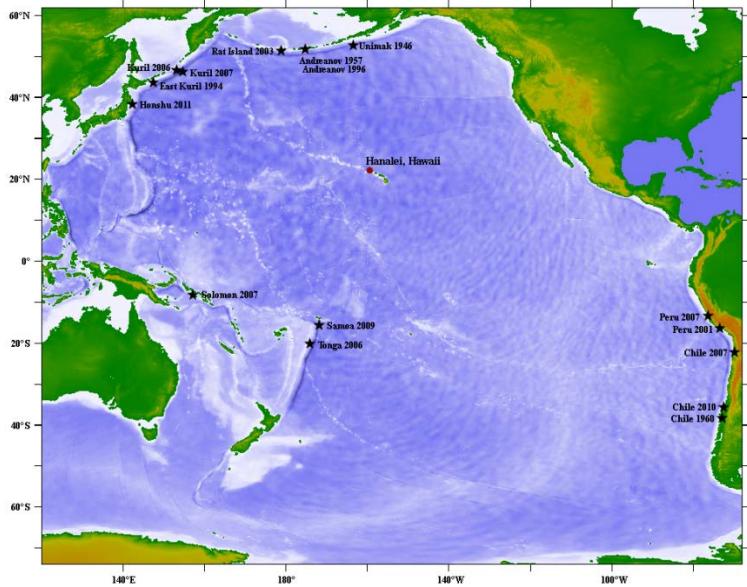


Figure 8. Location of Hanalei in relation to sixteen historical cases used to validate both forecast and reference model and as part of model stability and reliability tests.

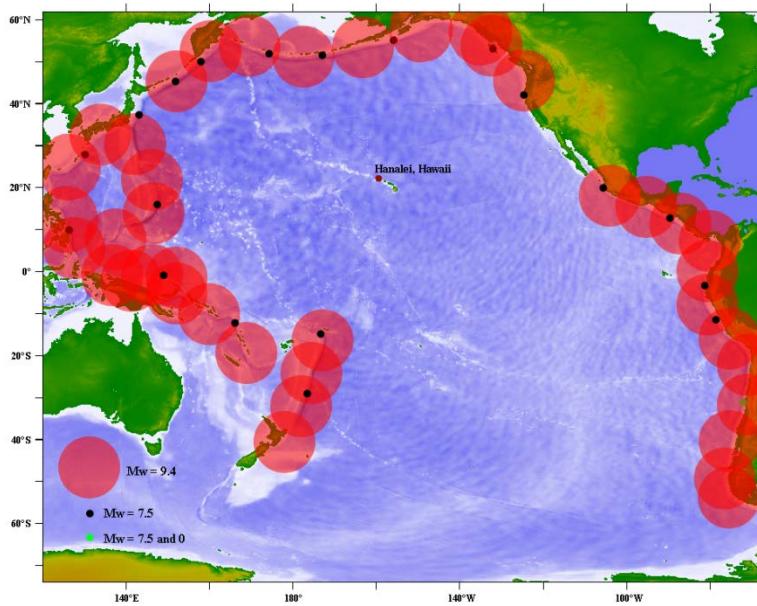


Figure 9. Location of Hanalei in relation to synthetic events (42-Mw=9.3, 20-Mw=7.5 and 1-Mw = ~0) tested.

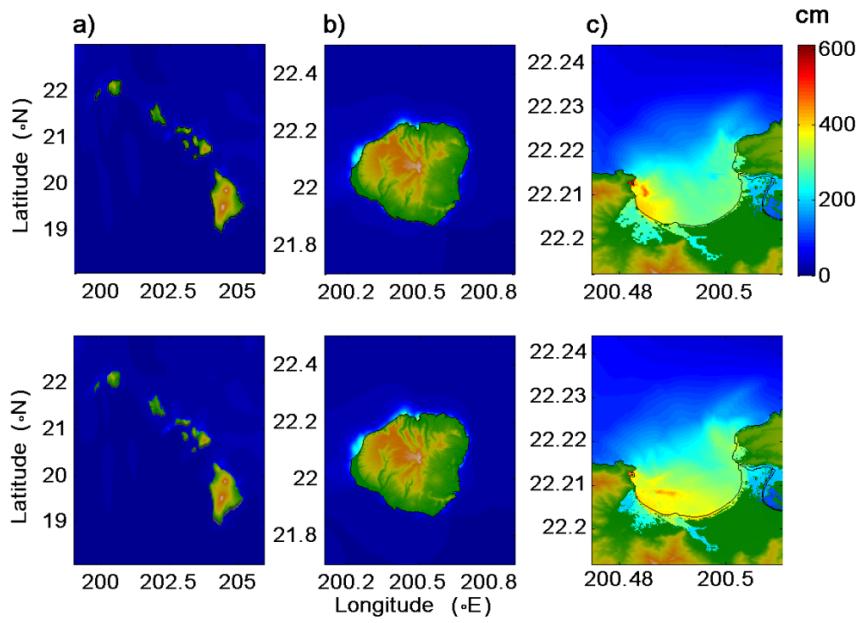


Figure 10. Maximum tsunami wave amplitude distribution of Unimak 1946 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

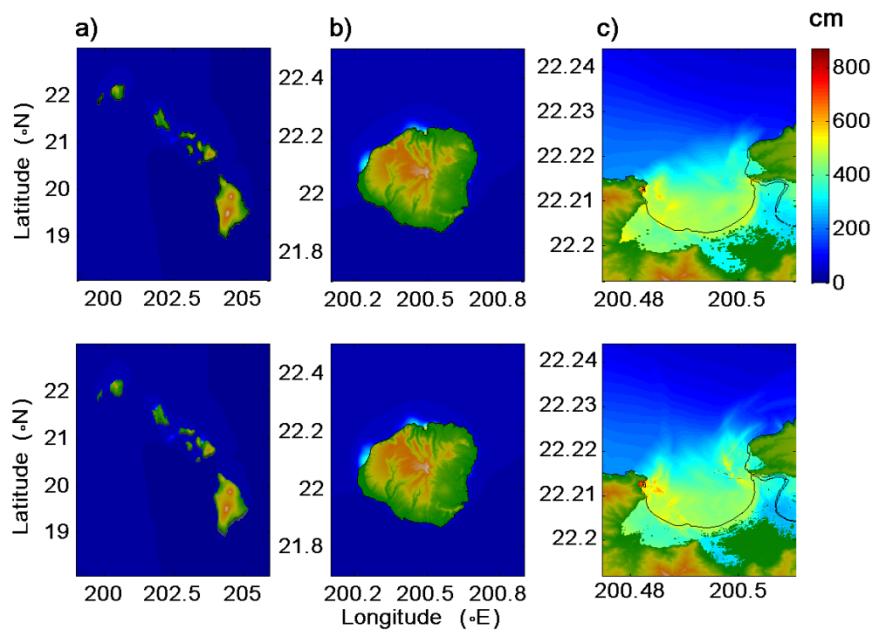


Figure 11. Maximum tsunami wave amplitude distribution of Andreanov 1957 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

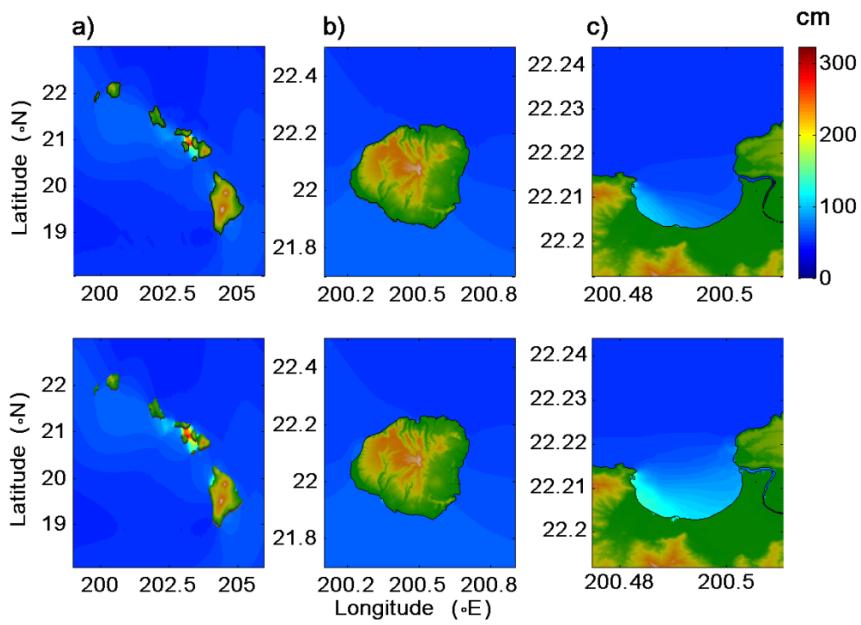


Figure 12. Maximum tsunami wave amplitude distribution of Chile 1960 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

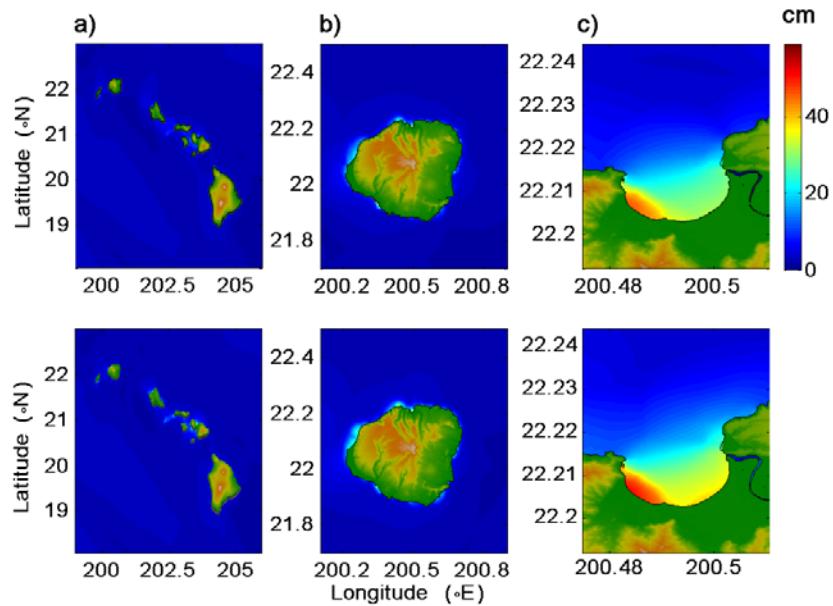


Figure 13. Maximum tsunami wave amplitude distribution of East Kuril 1994 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

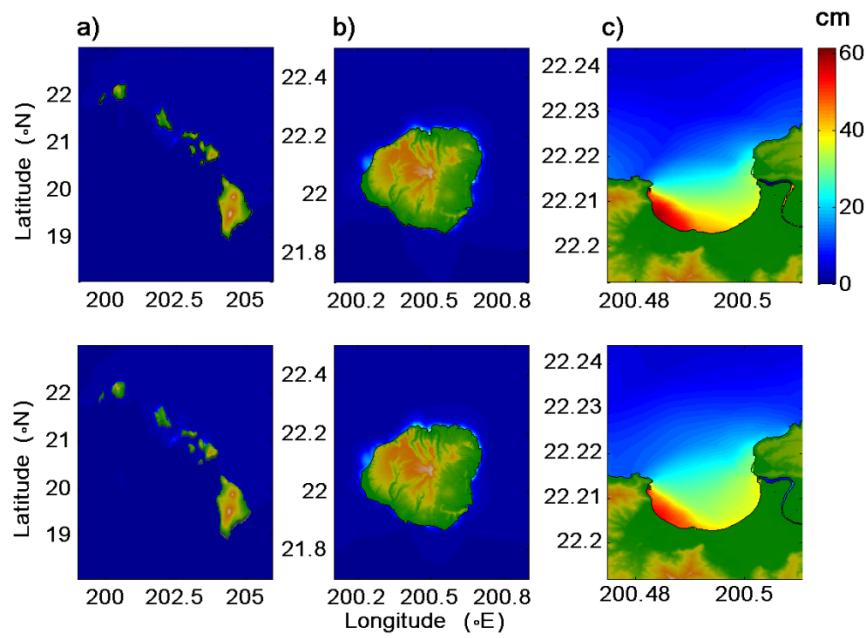


Figure 14. Maximum tsunami wave amplitude distribution of Andreanov 1996 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

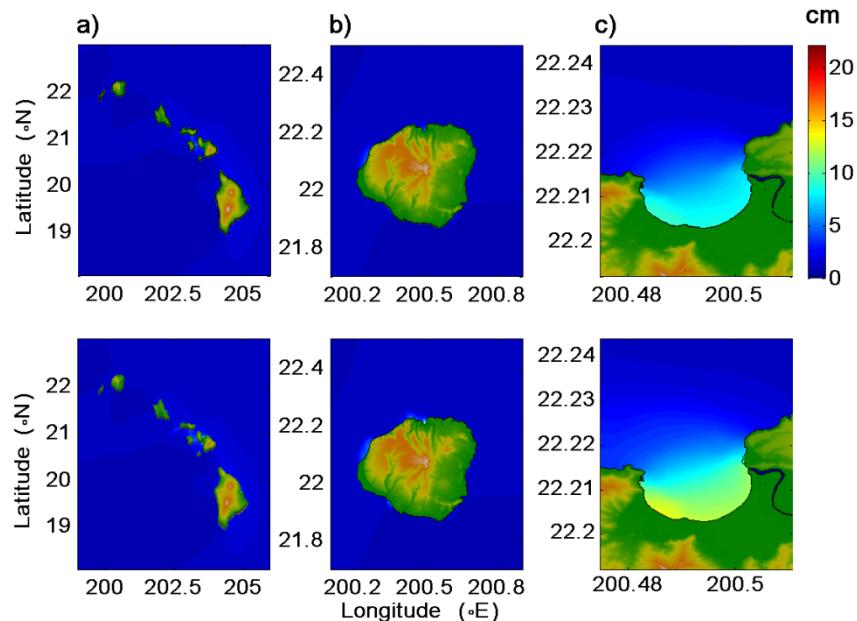


Figure 15. Maximum tsunami wave amplitude distribution of Peru 2001 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

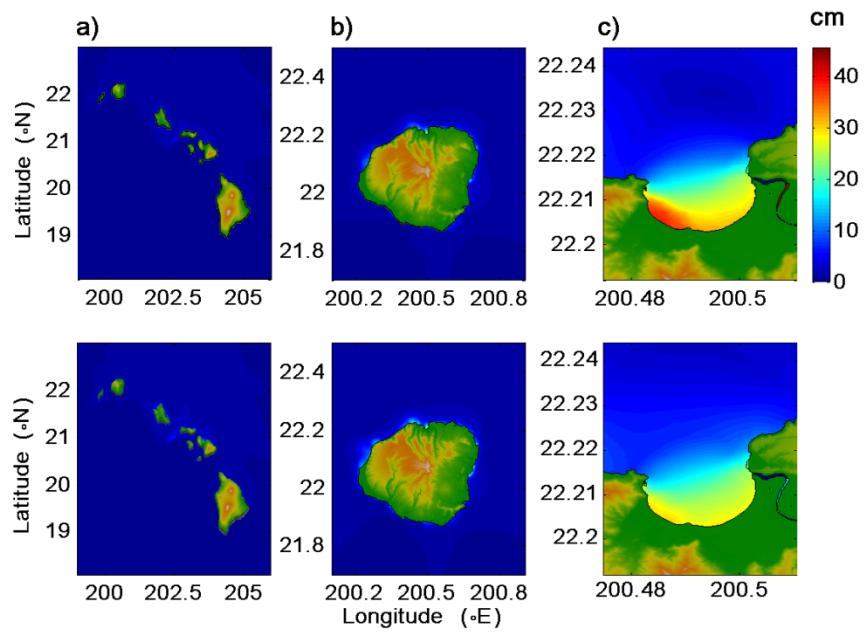


Figure 16. Maximum tsunami wave amplitude distribution of Rat Island 2003 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

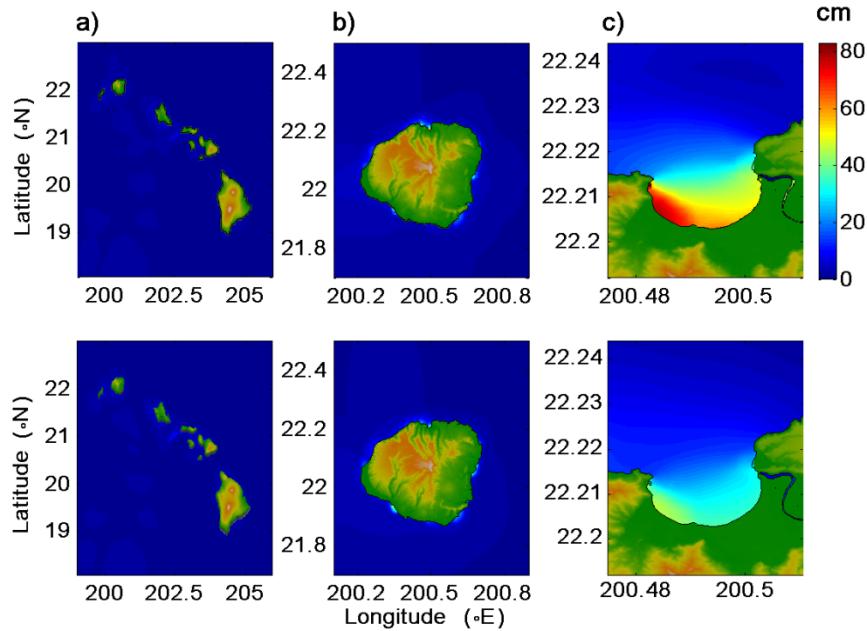


Figure 17. Maximum tsunami wave amplitude distribution of Tonga 2006 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

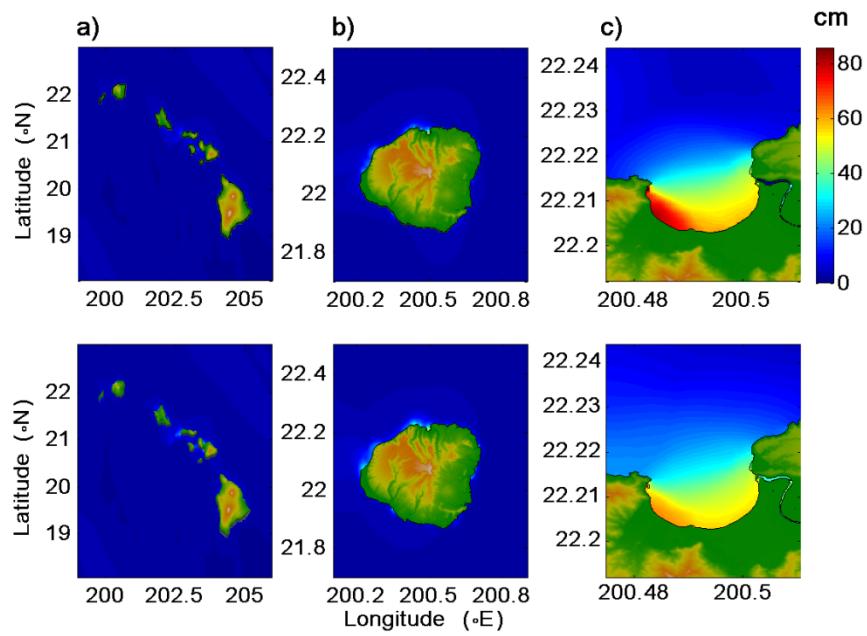


Figure 18. Maximum tsunami wave amplitude distribution of Kuril 2006 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

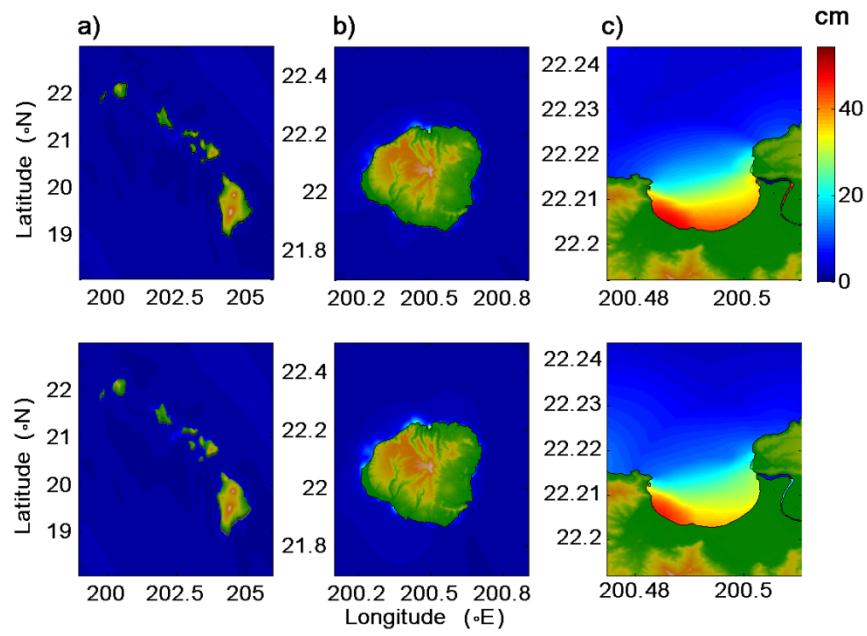


Figure 19. Maximum tsunami wave amplitude distribution of Kuril 2007 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

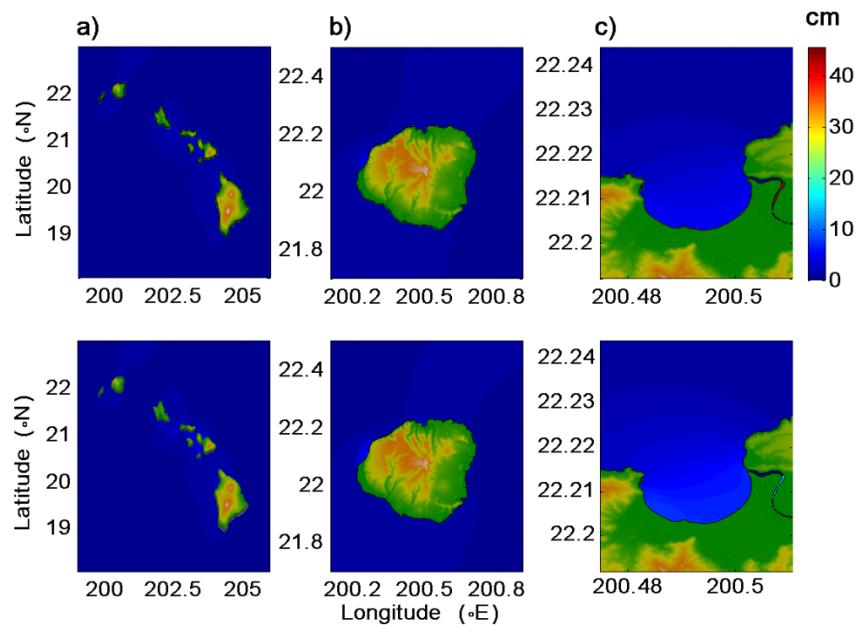


Figure 20. Maximum tsunami wave amplitude distribution of Solomon 2007 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

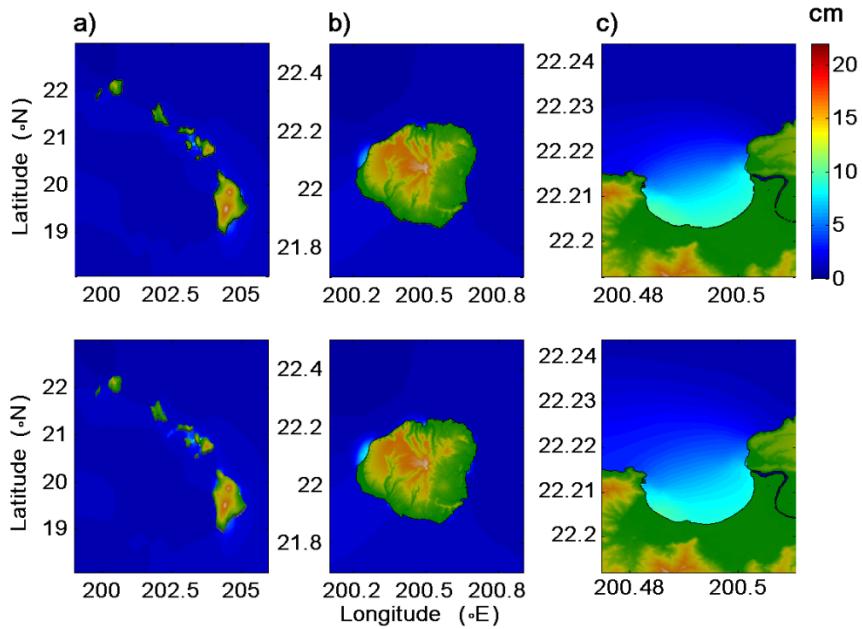


Figure 21. Maximum tsunami wave amplitude distribution of Peru 2007 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

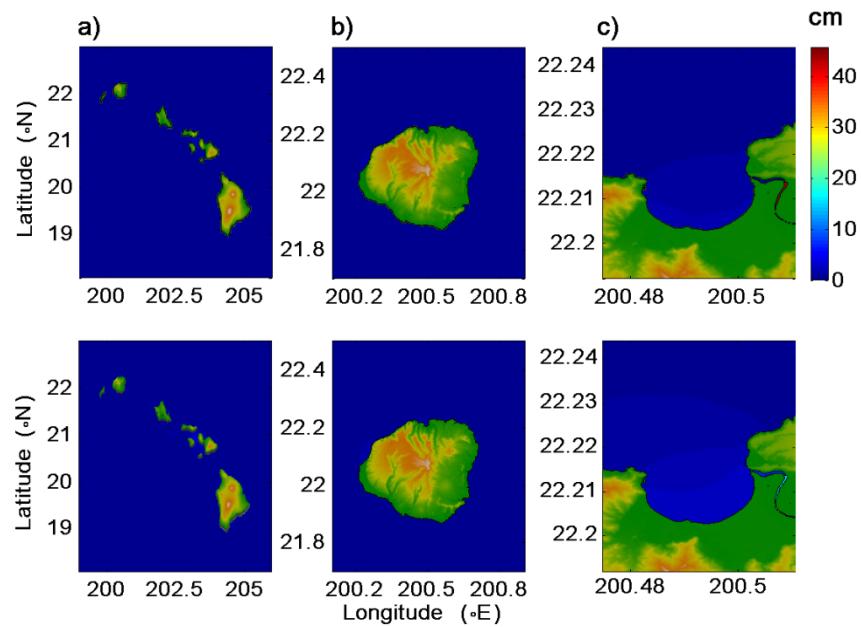


Figure 22. Maximum tsunami wave amplitude distribution of Chile 2007 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

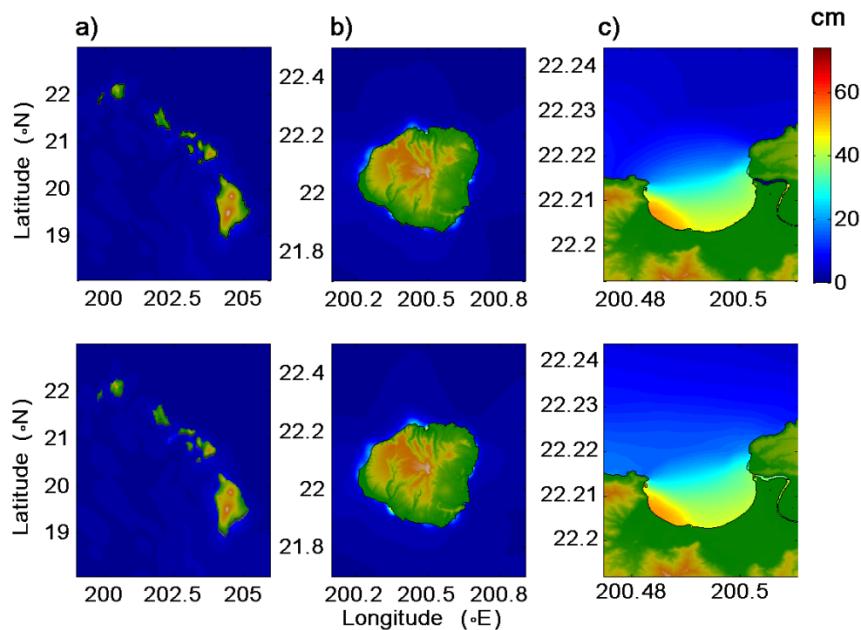


Figure 23. Maximum tsunami wave amplitude distribution of Samoa 2007 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

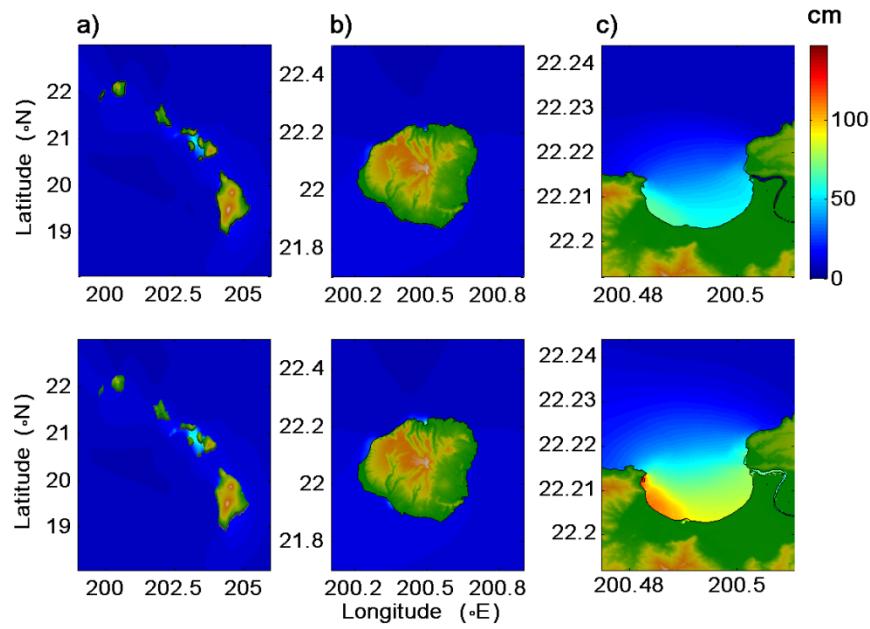


Figure 24. Maximum tsunami wave amplitude distribution of Chile 2010 tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

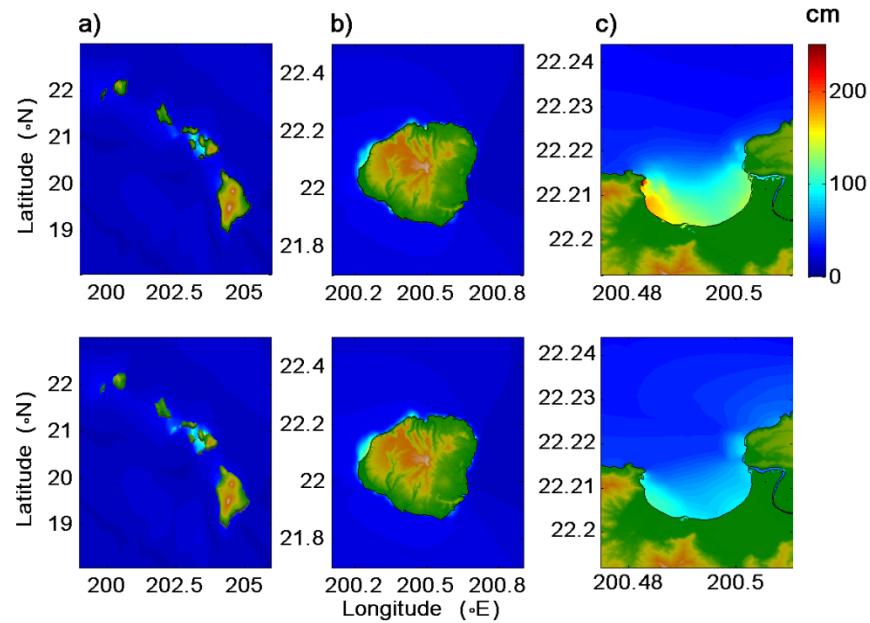


Figure 25. Maximum tsunami wave amplitude distribution of 11 March 2011 Honshu tsunami for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

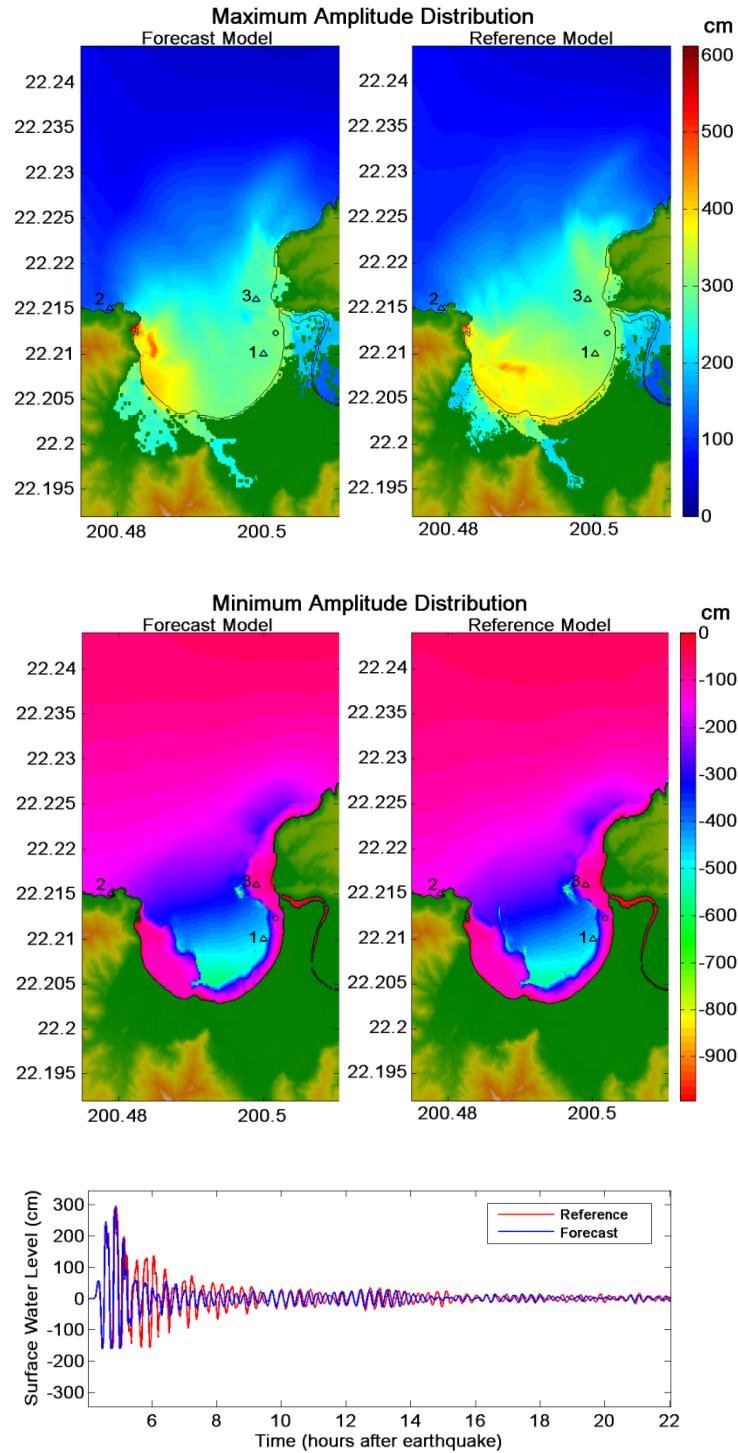


Figure 26. Tsunami wave amplitude distribution of Unimak 1946 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Triangles are locations of historical tsunami wave height (NGDC) based on eyewitness accounts. Circle is the selected warning point location.

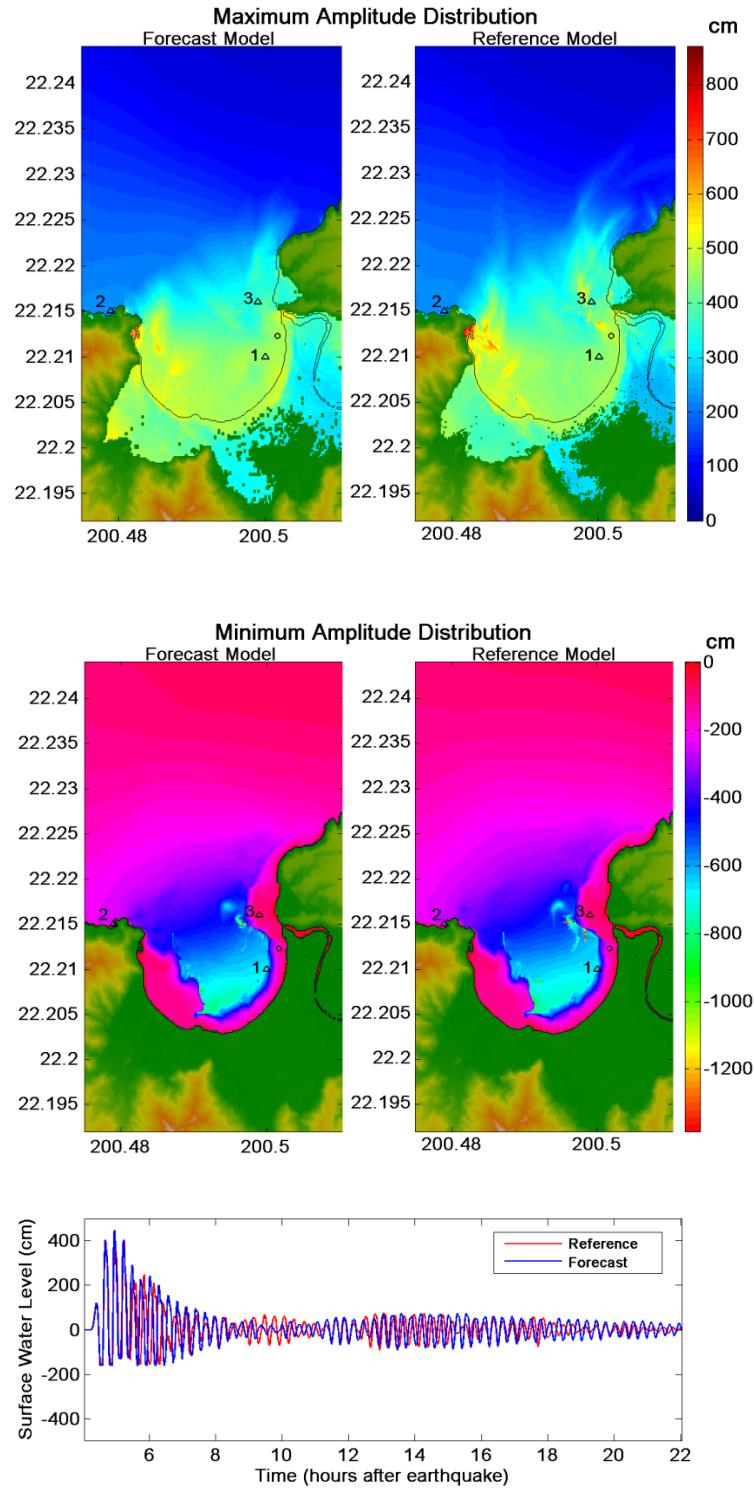


Figure 27. Tsunami wave amplitude distribution of Andreanov 1957 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Triangles are locations of historical tsunami wave height (NGDC) based on eyewitness accounts. Circle is the selected warning point location.

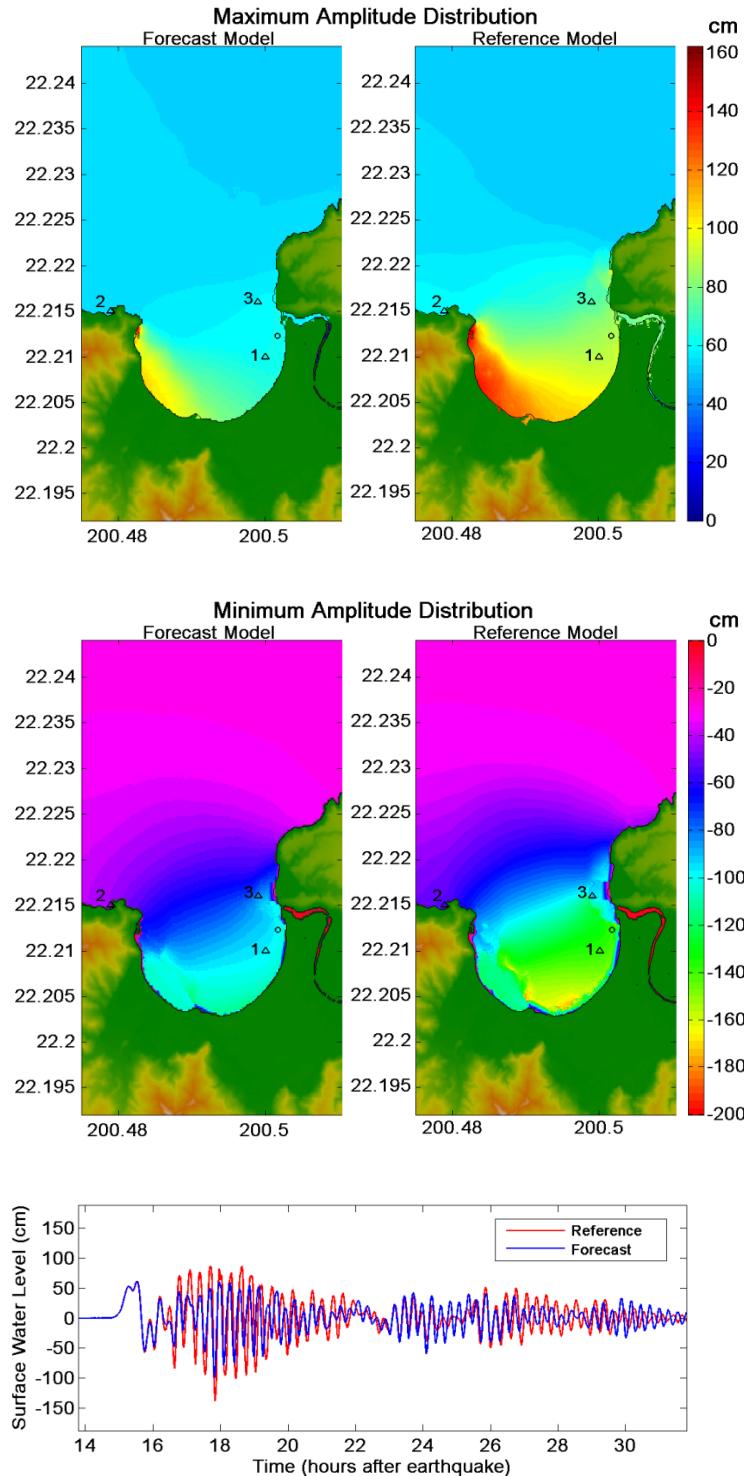


Figure 28. Tsunami wave amplitude distribution of Chile 1960 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Triangles are locations of historical tsunami wave height (NGDC) based on eyewitness accounts. Circle is the selected warning point location.

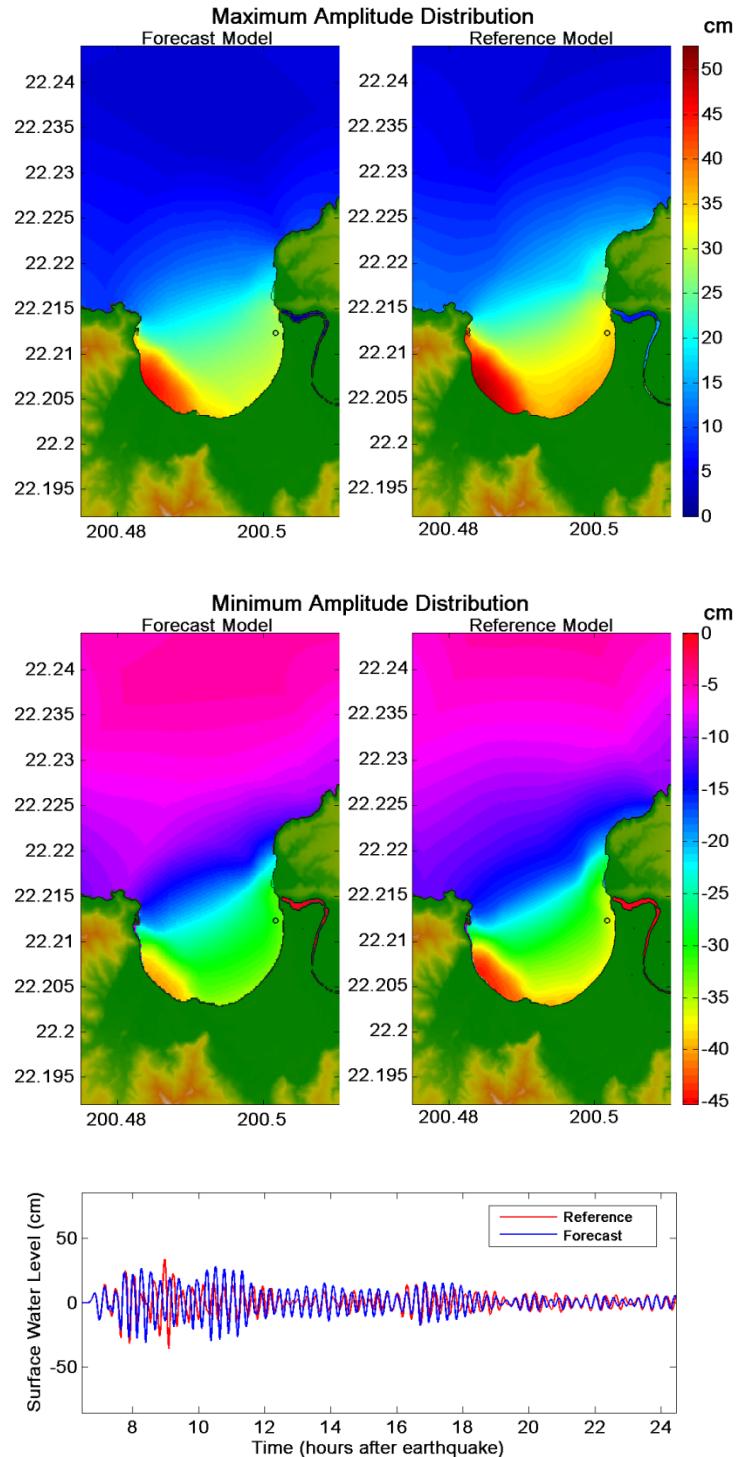


Figure 29. Tsunami wave amplitude distribution of East Kuril 1994 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

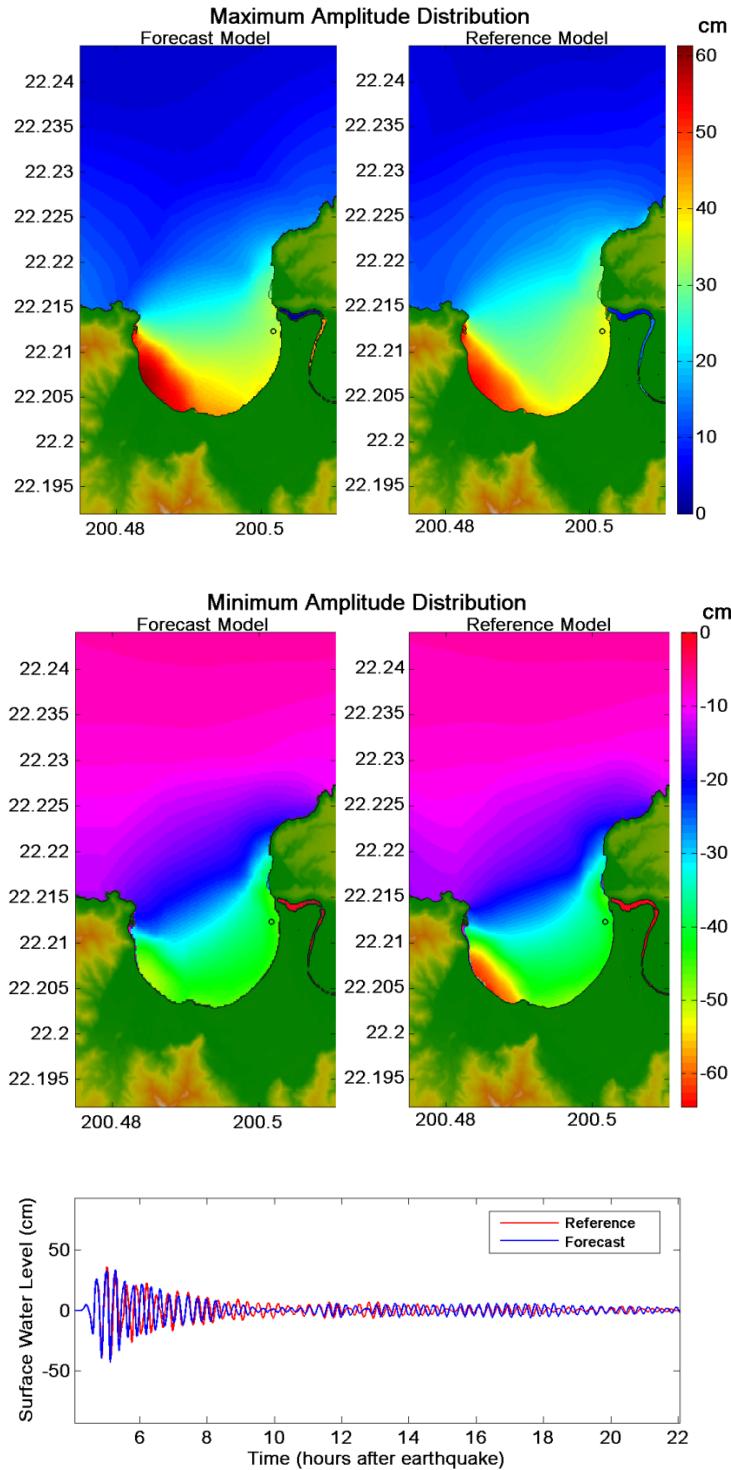


Figure 30. Tsunami wave amplitude distribution of Andreanov 1996 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

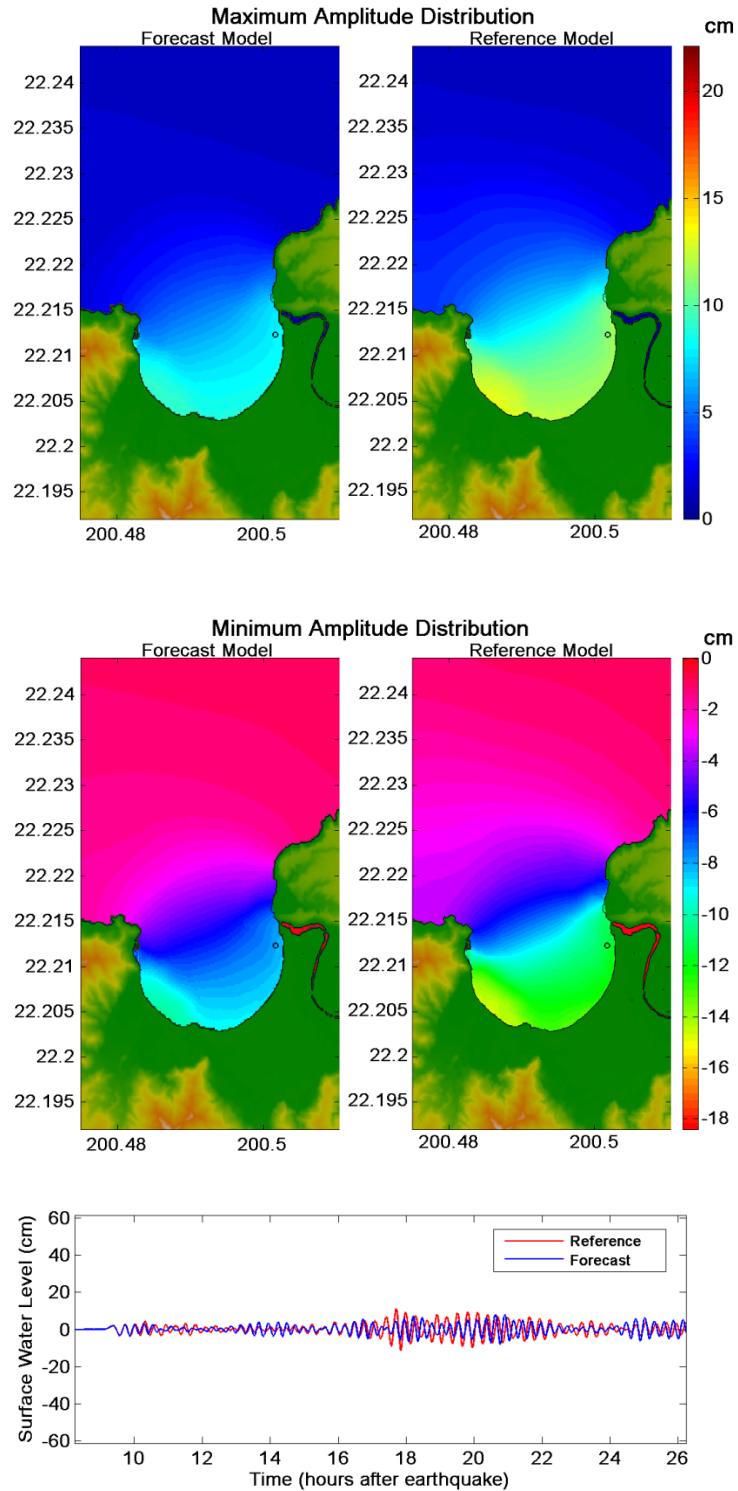


Figure 31. Tsunami wave amplitude distribution of Peru 2001 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

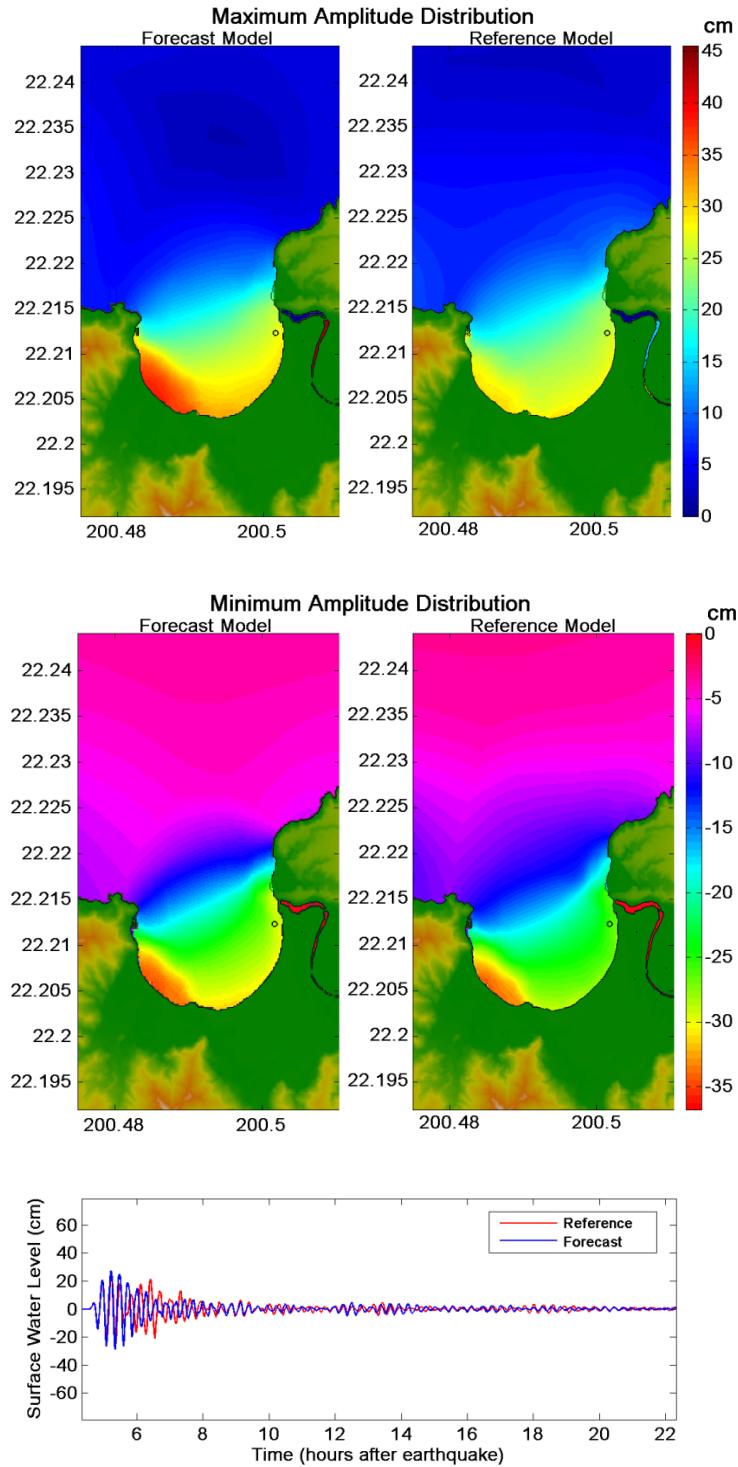


Figure 32. Tsunami wave amplitude distribution of Rat Island 2003 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

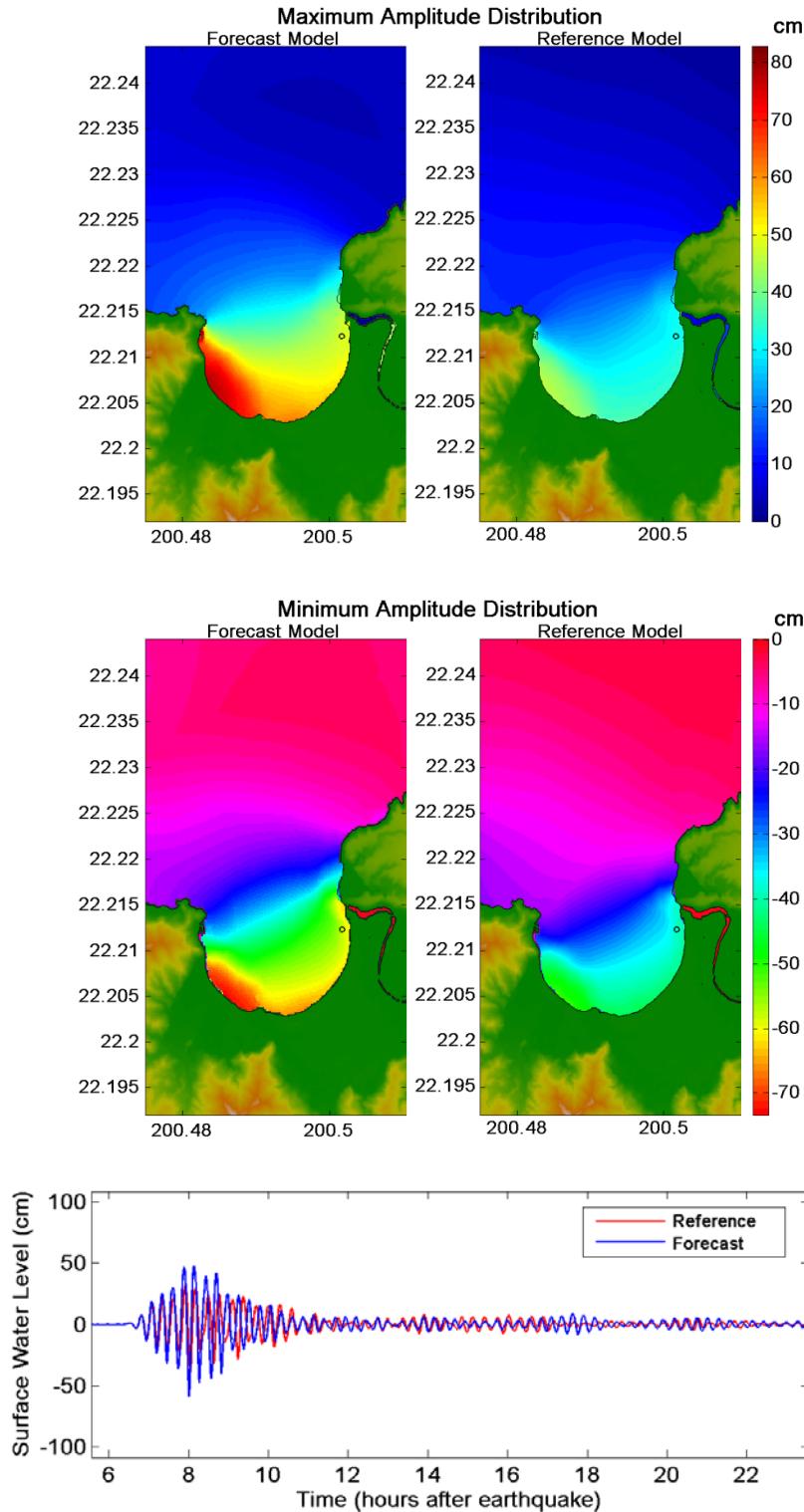


Figure 33. Tsunami wave amplitude distribution of Tonga 2006 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

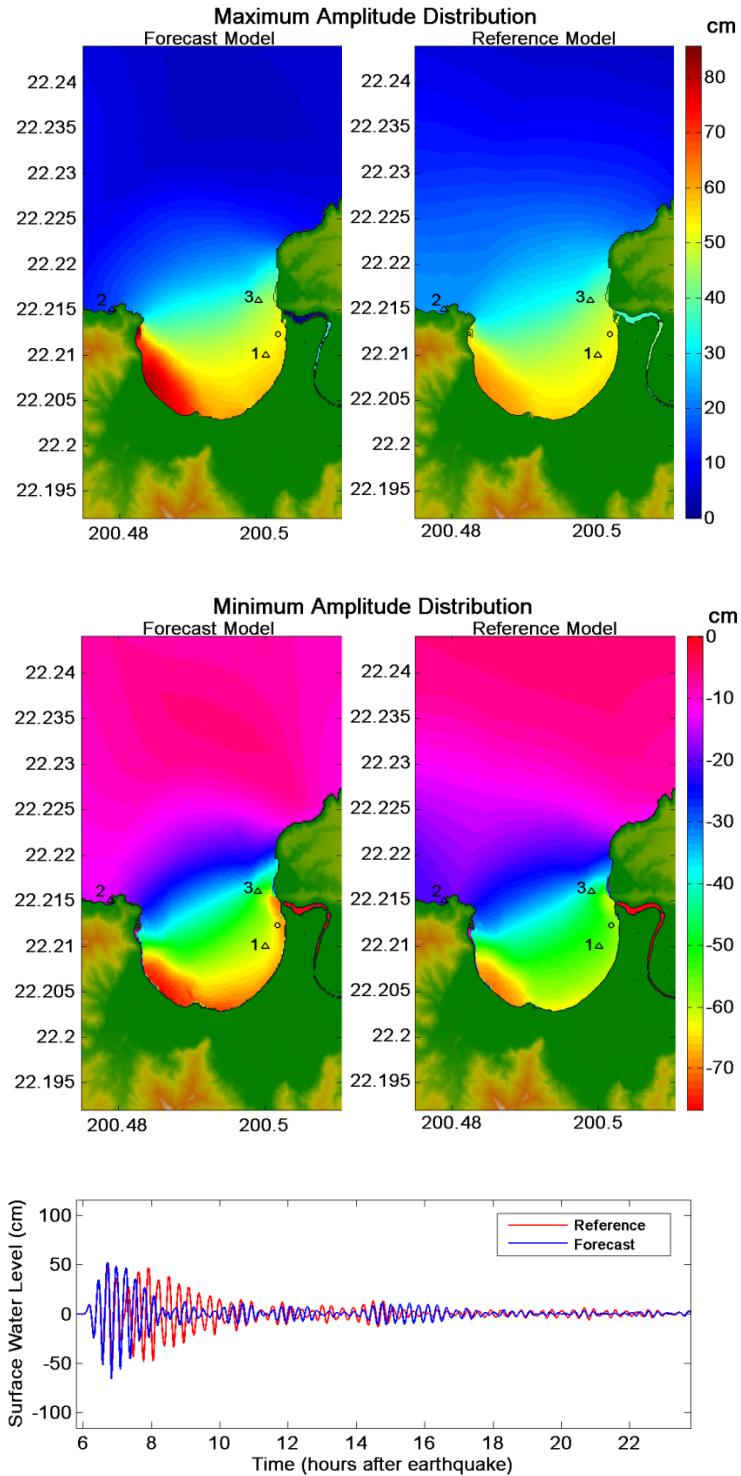


Figure 34. Tsunami wave amplitude distribution of Kuril 2006 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Triangles are locations of historical tsunami wave height (NGDC) based on eyewitness accounts. Circle is the selected warning point location.

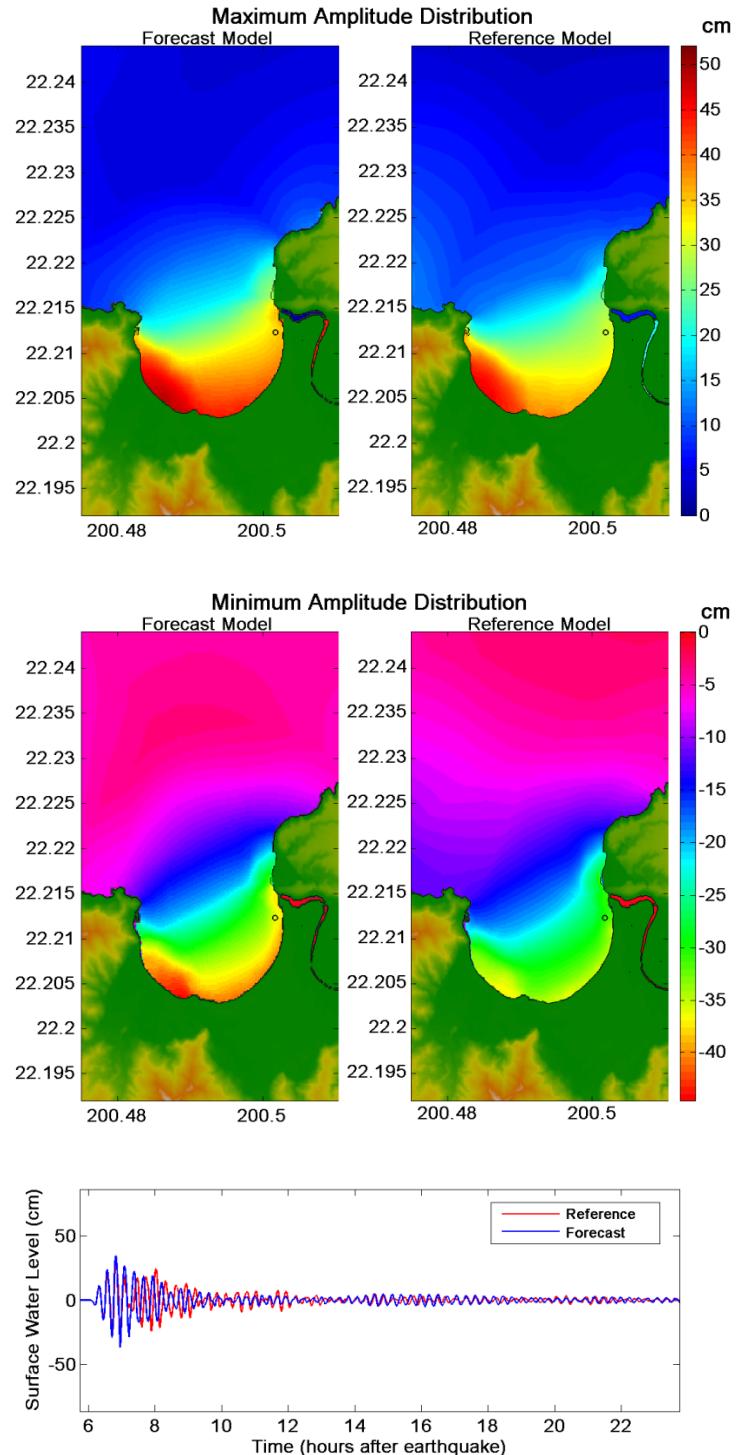


Figure 35. Tsunami wave amplitude distribution of Kuril 2007 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

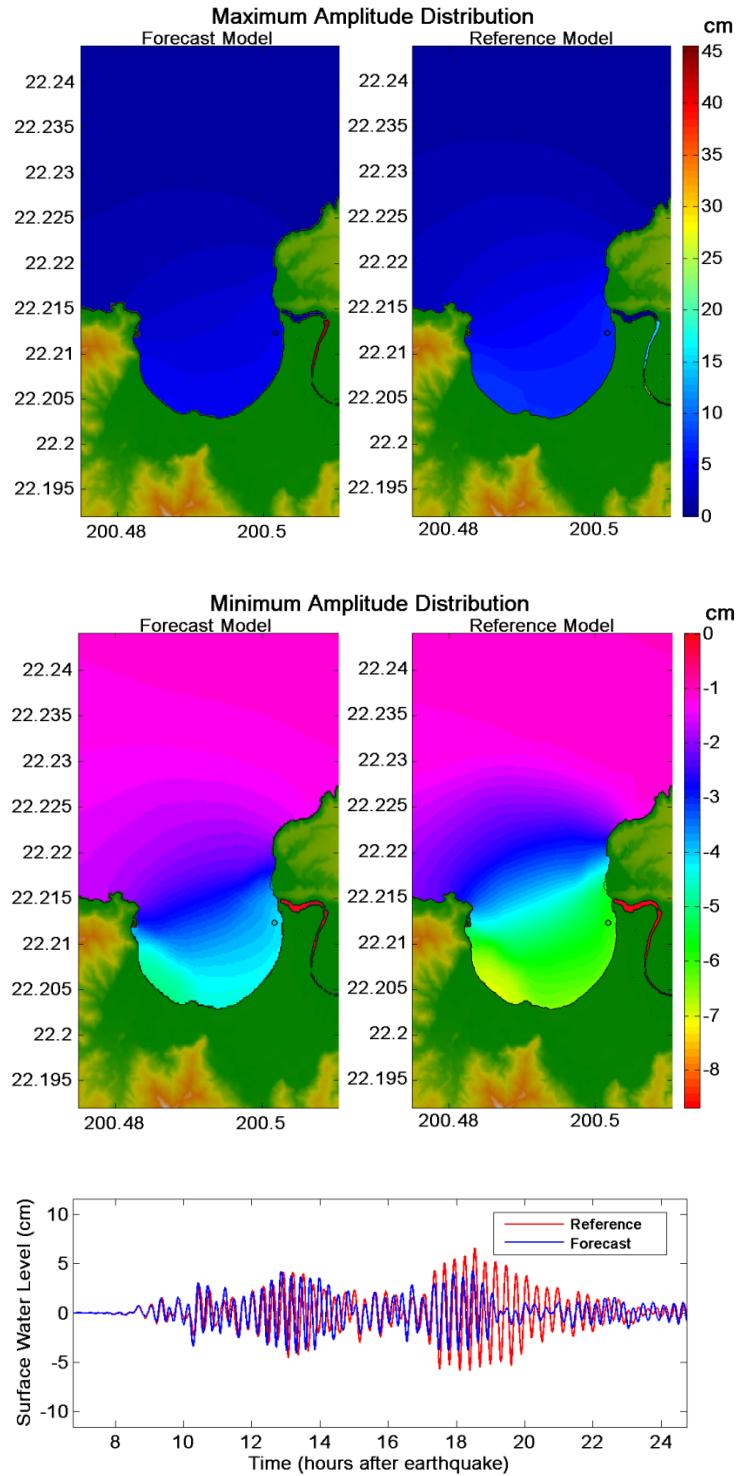


Figure 36. Tsunami wave amplitude distribution of Solomon 2007 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

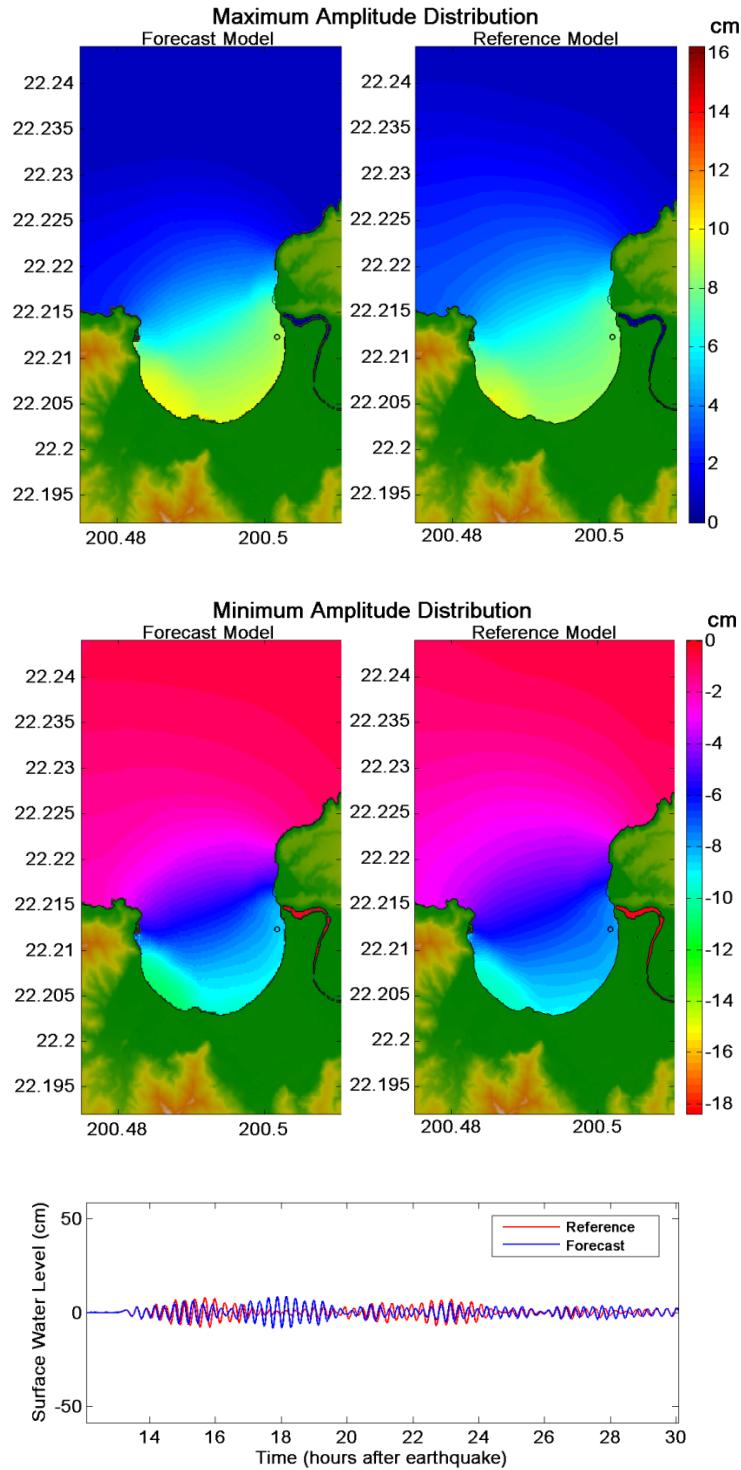


Figure 37. Tsunami wave amplitude distribution of Peru 2007 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

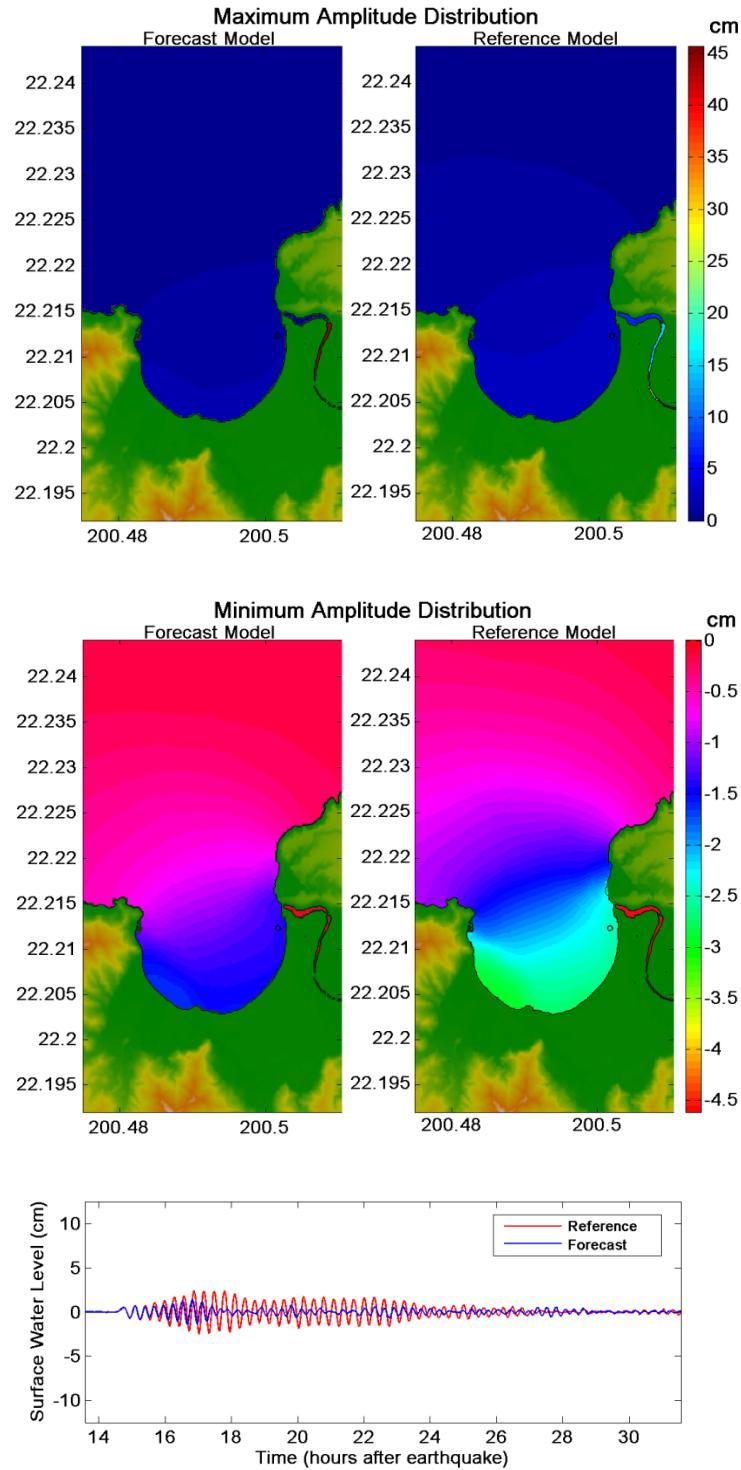


Figure 38. Tsunami wave amplitude distribution of Chile 2007 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

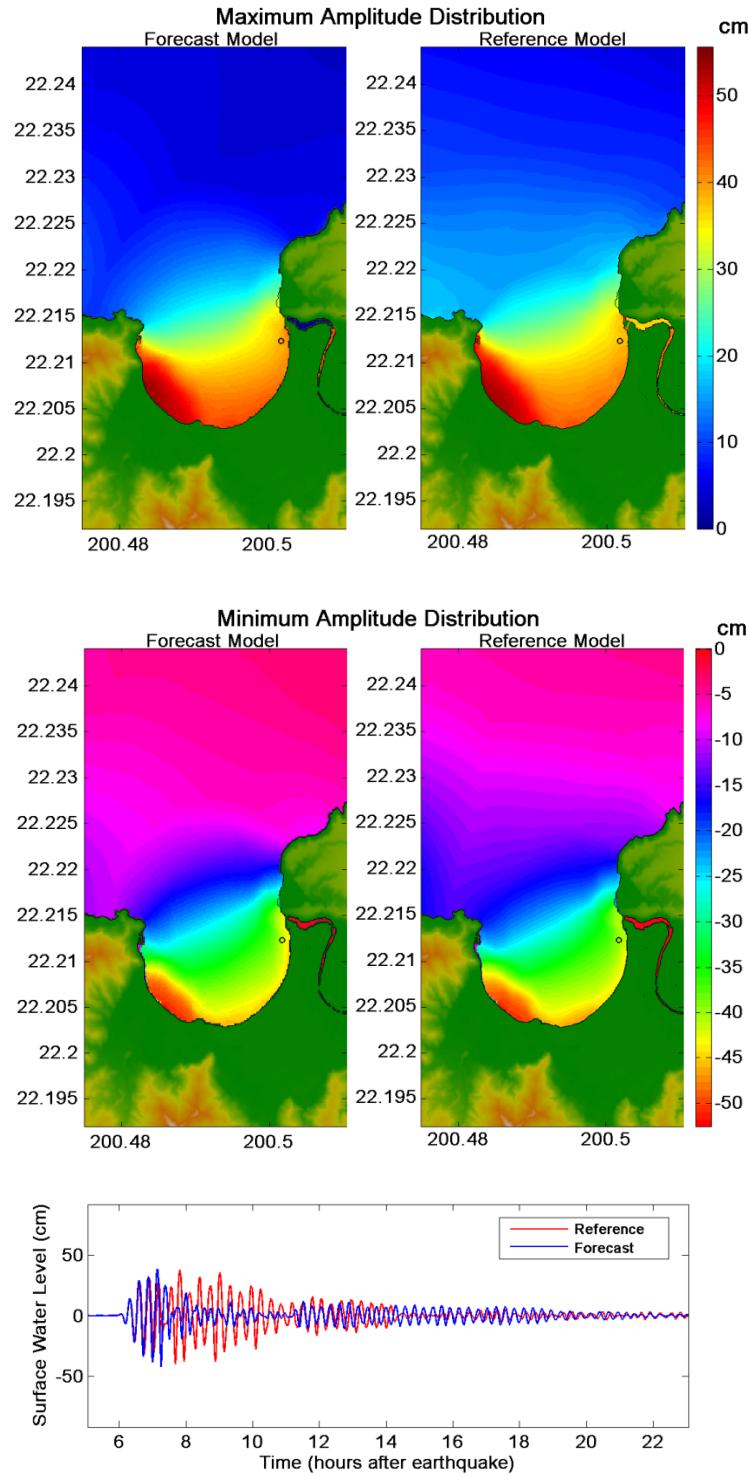


Figure 39. Tsunami wave amplitude distribution of Samoa 2009 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

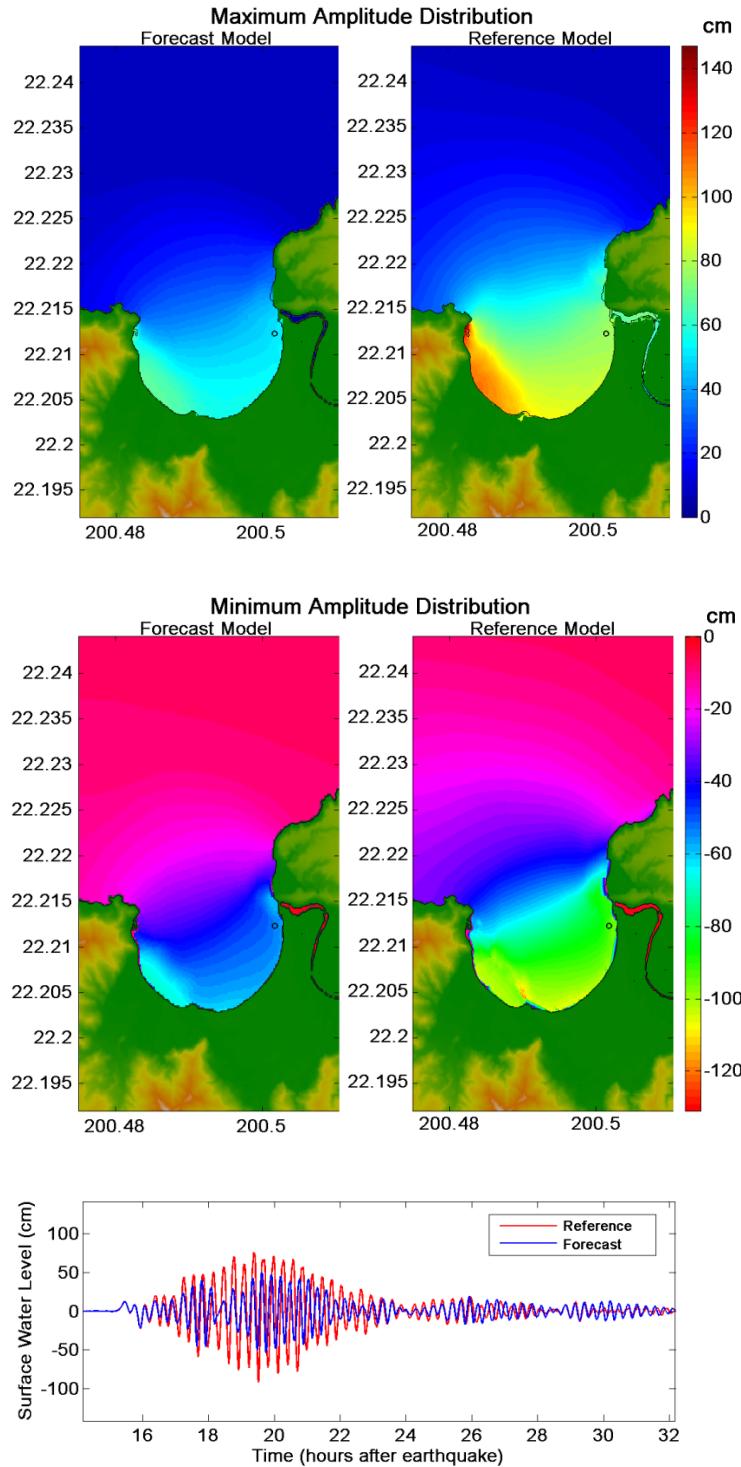


Figure 40. Tsunami wave amplitude distribution of Chile 2010 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

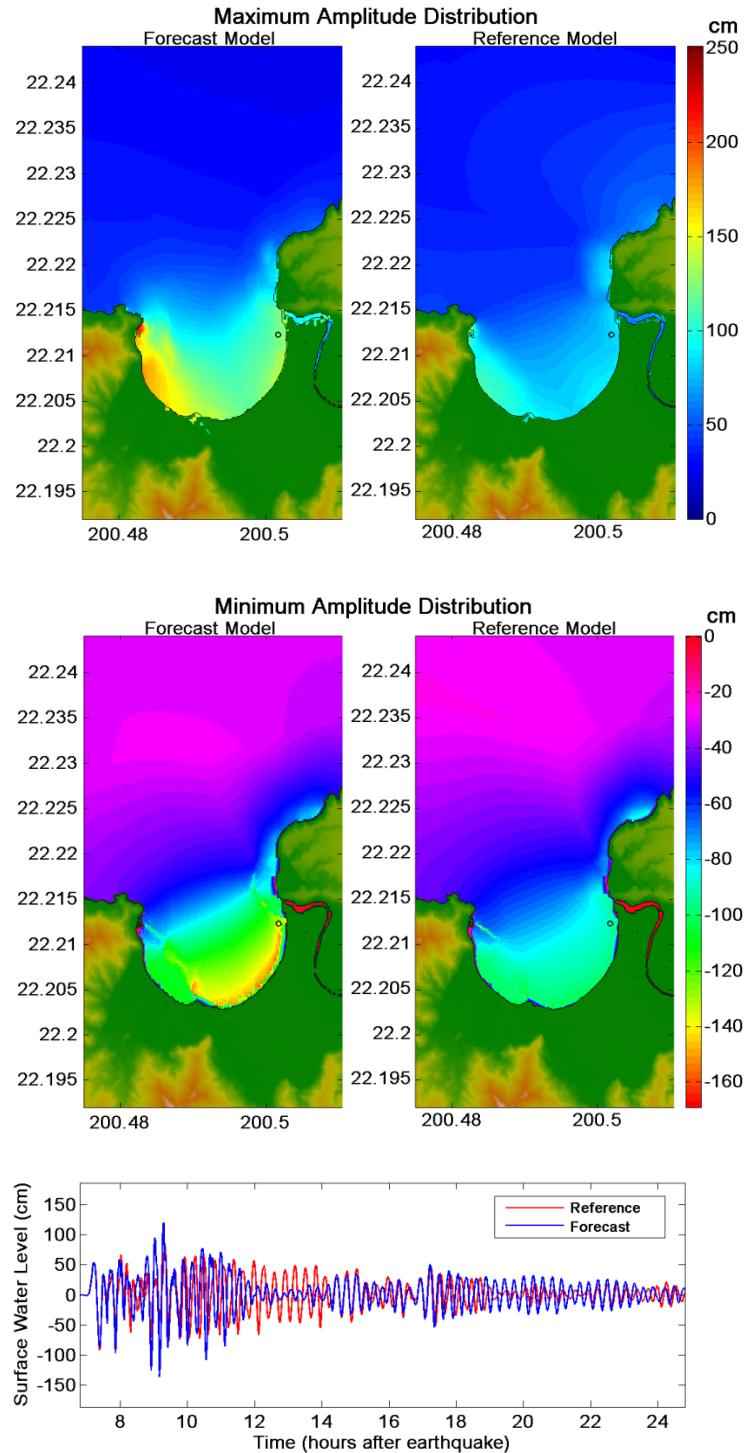


Figure 41. Tsunami wave amplitude distribution of 11 March 2011 tsunami at C-grid level; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

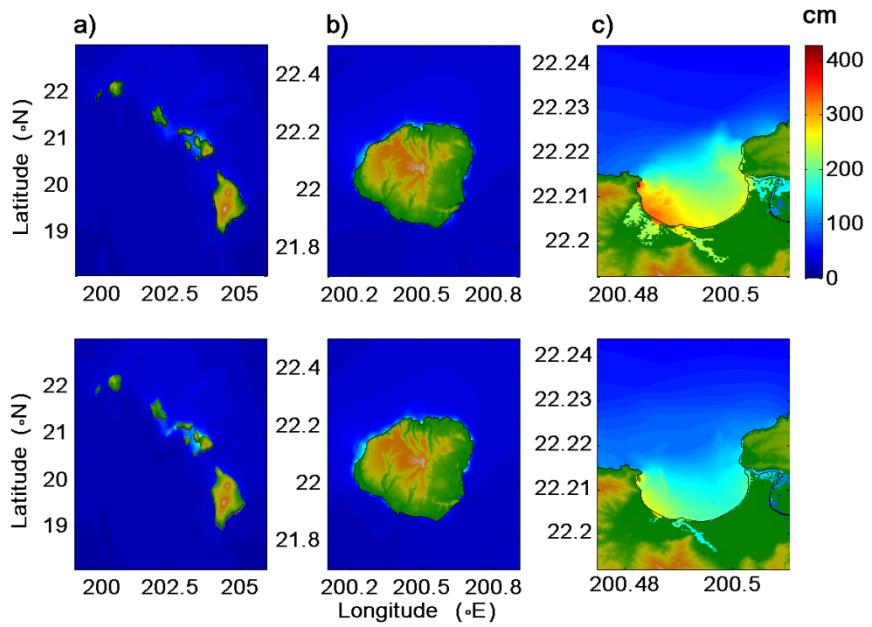


Figure 42. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami AC01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

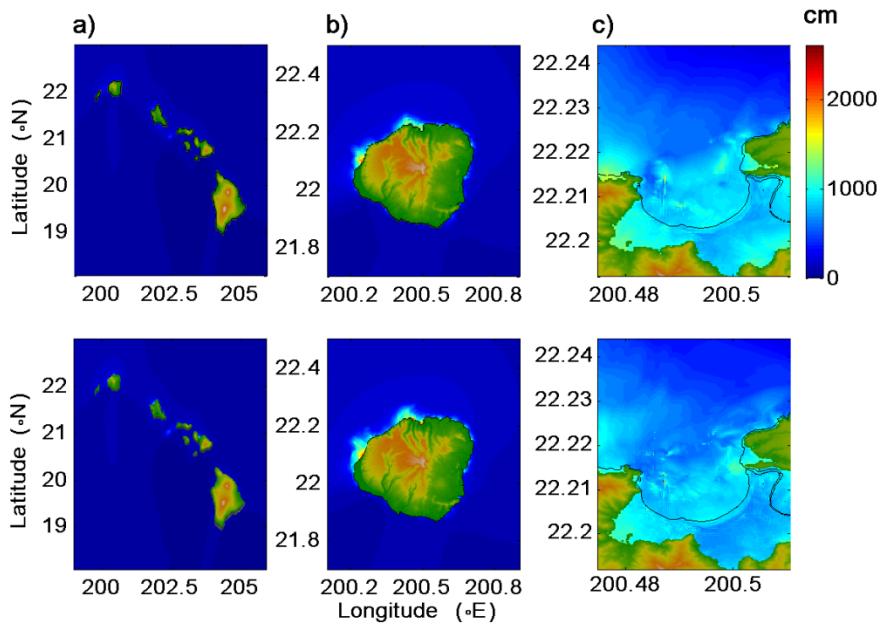


Figure 43. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami AC11-20 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

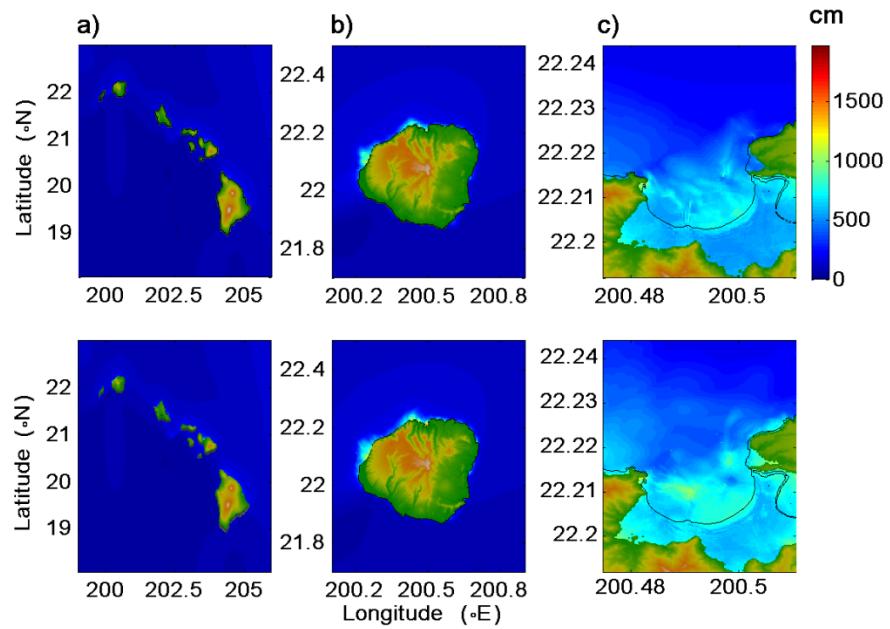


Figure 44. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami AC21-30 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

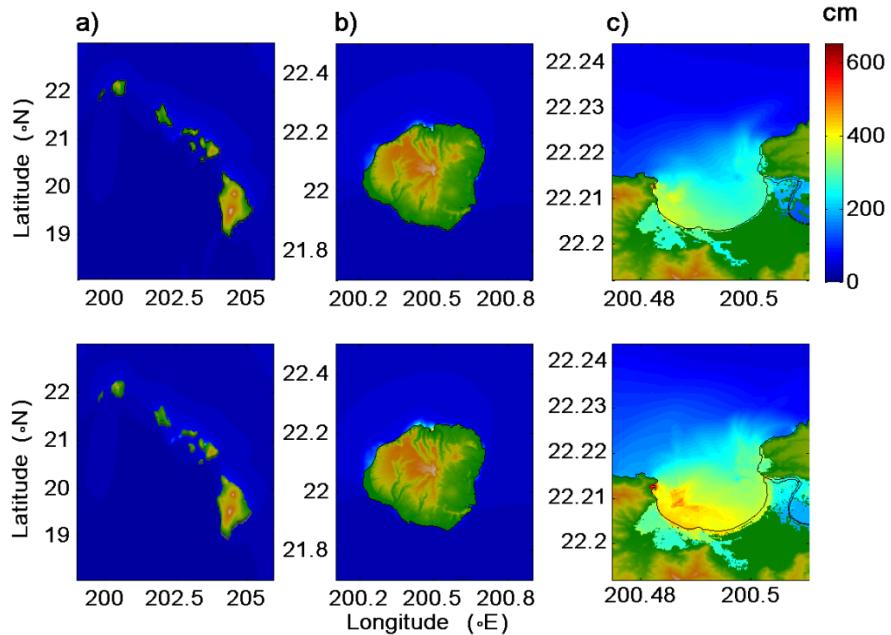


Figure 45. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami AC31-40 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

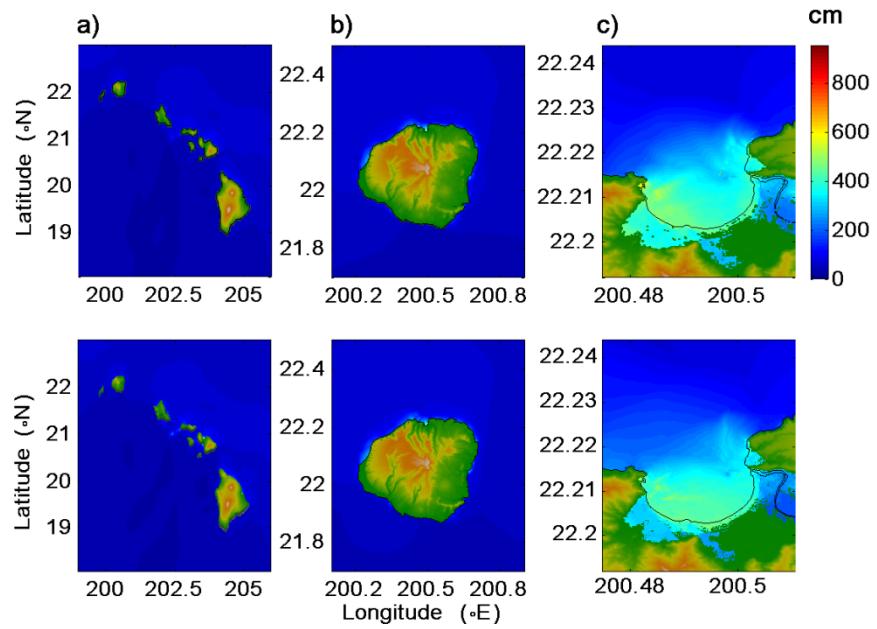


Figure 46. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami AC41-50 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

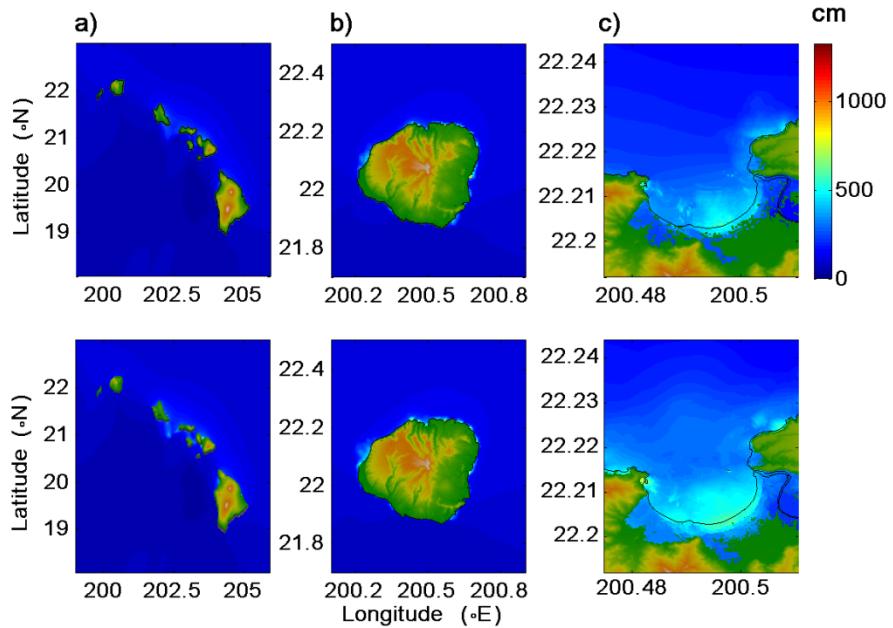


Figure 47. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami AC51-60 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

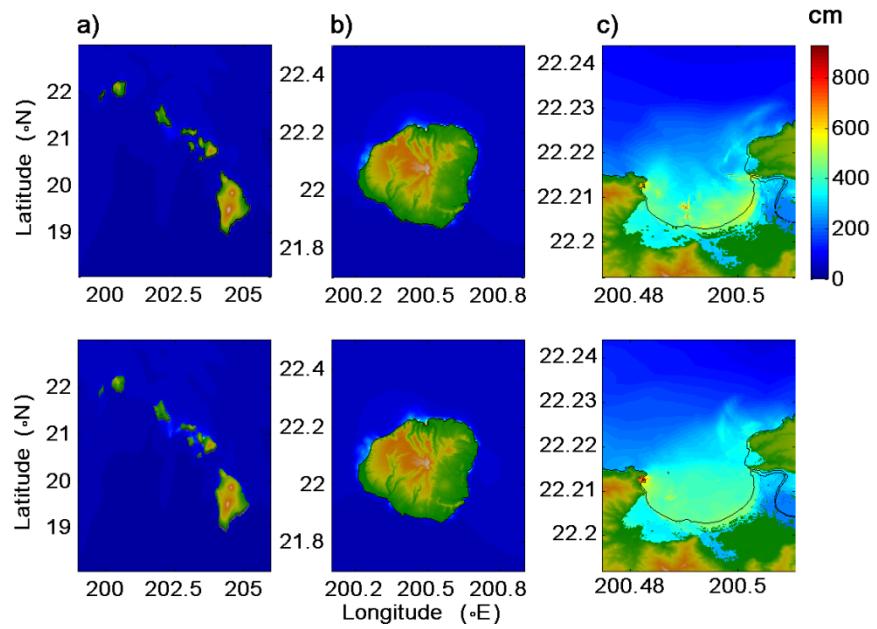


Figure 48. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami AC56-65 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

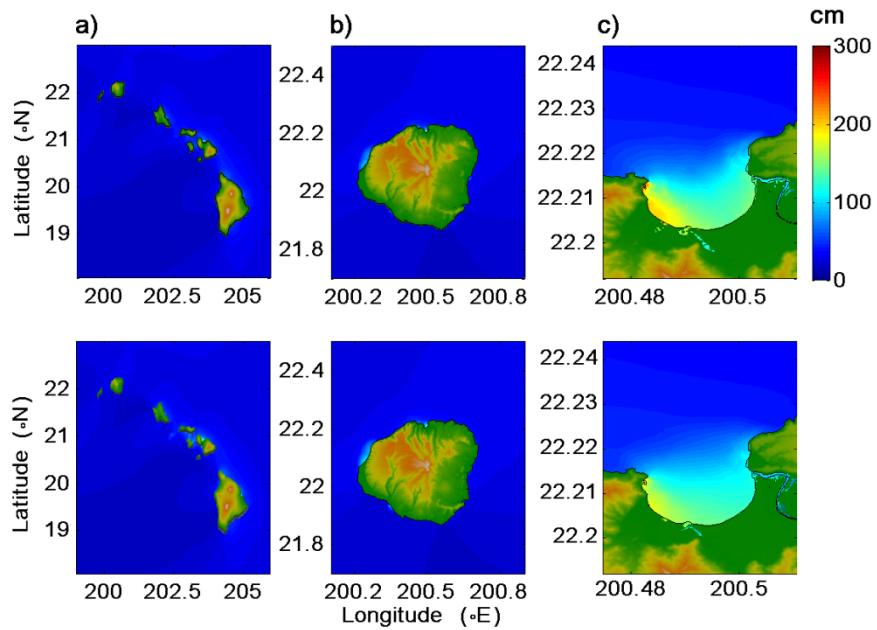


Figure 49. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

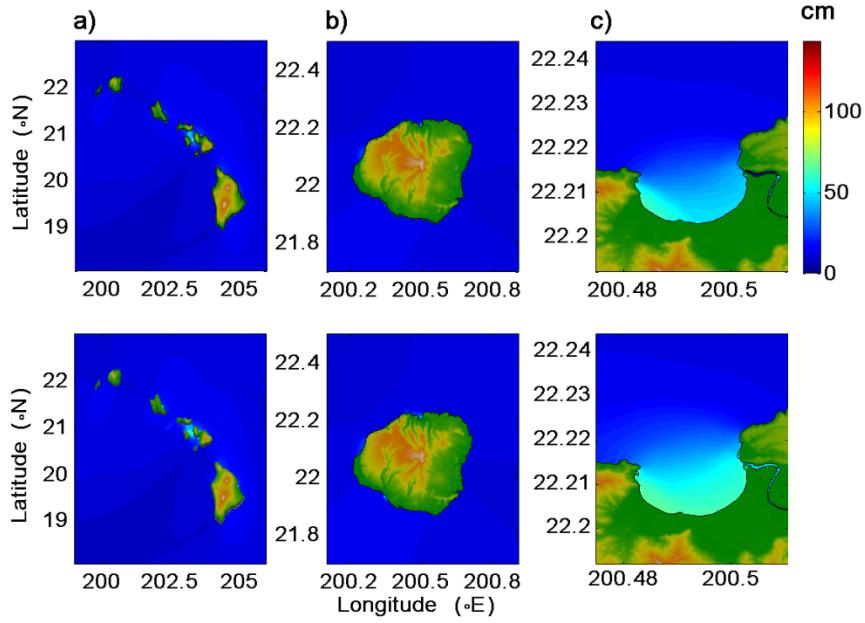


Figure 50. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS11-20 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

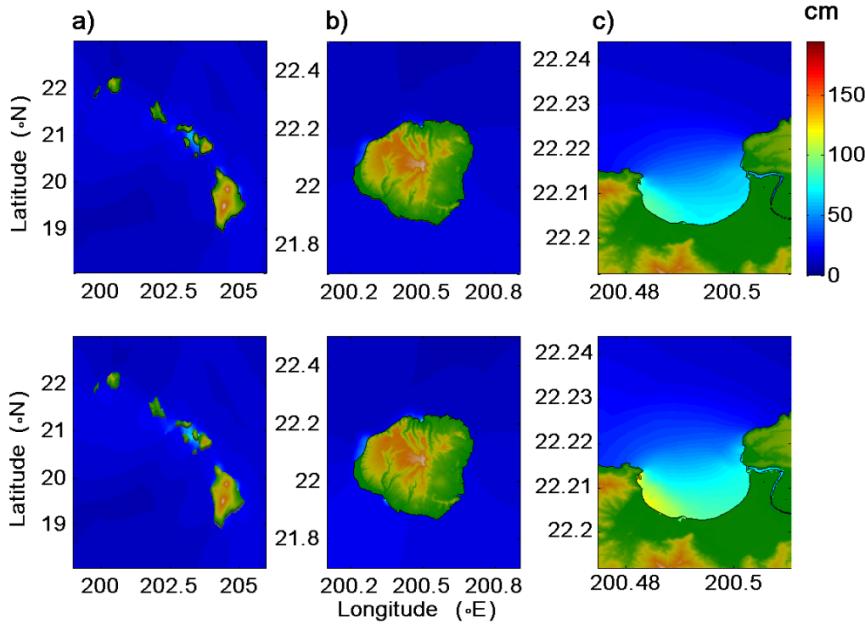


Figure 51. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS21-30 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

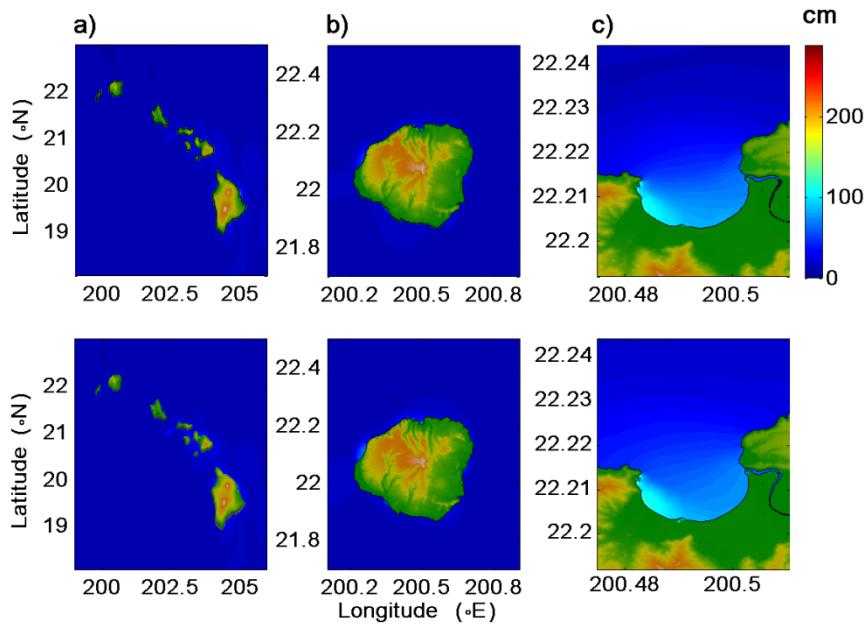


Figure 52. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS31-40 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

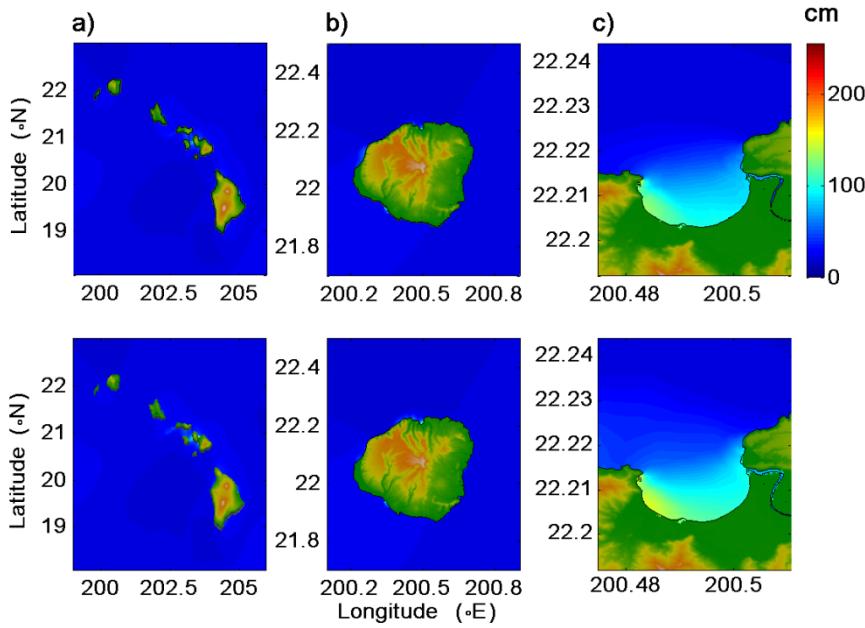


Figure 53. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS41-50 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

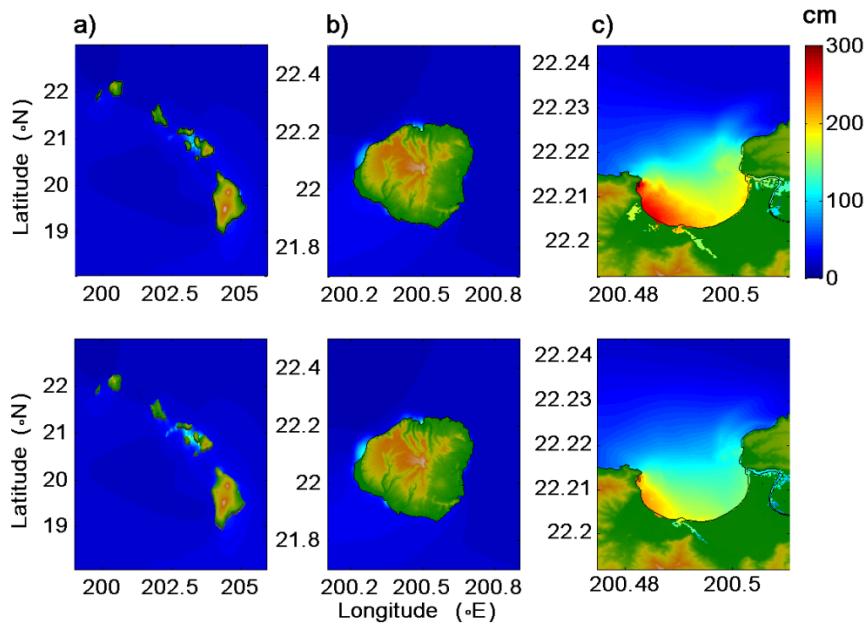


Figure 54. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS51-60 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

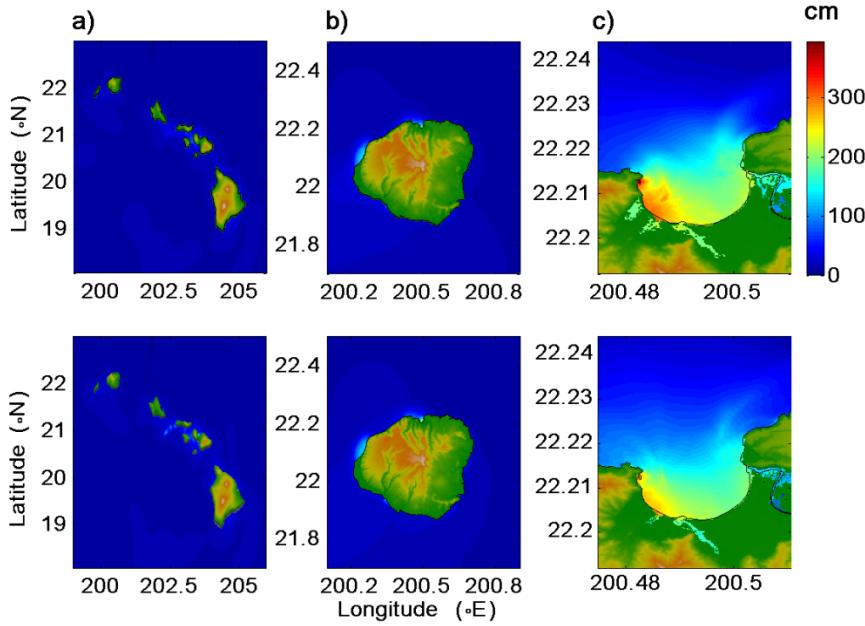


Figure 55. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS61-70 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

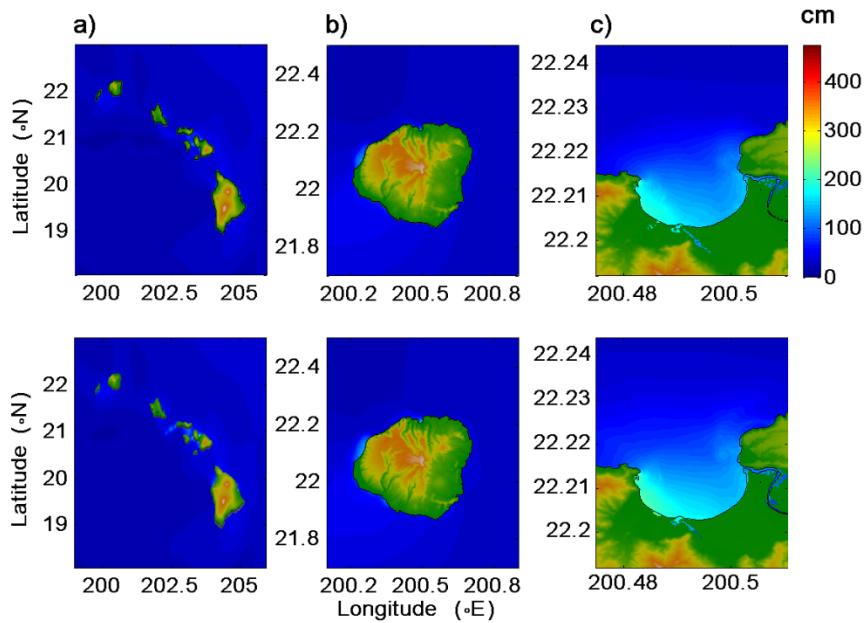


Figure 56. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS71-80 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

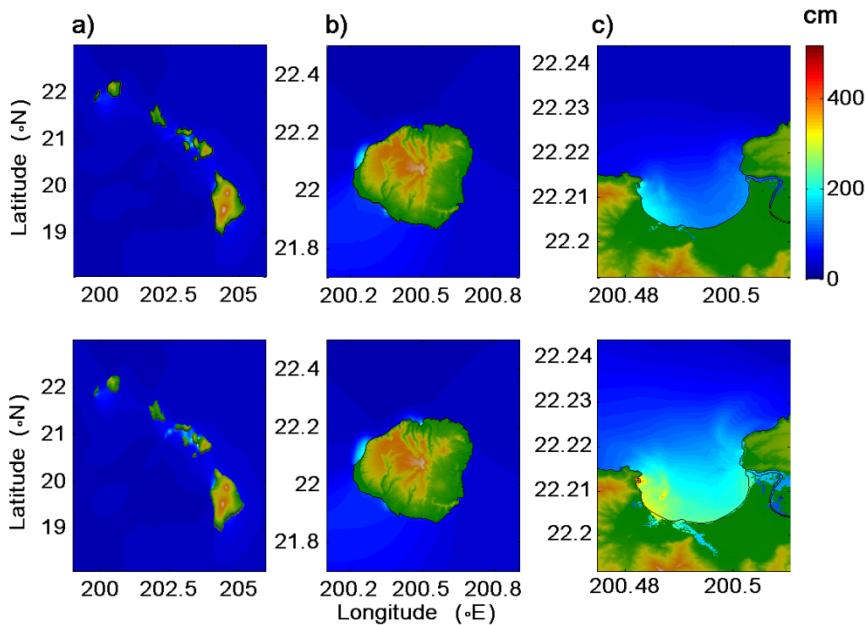


Figure 57. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS81-90 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

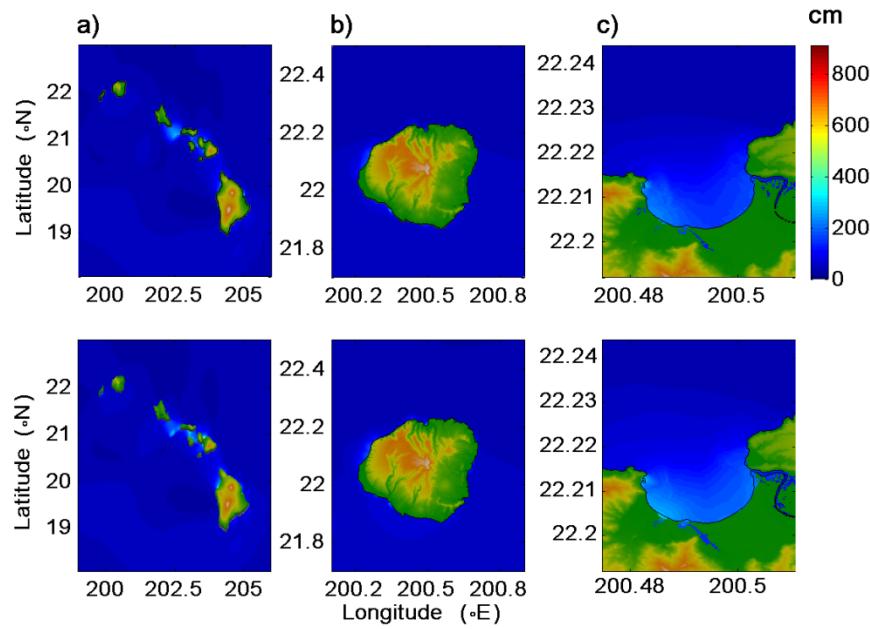


Figure 58. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS91-100 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

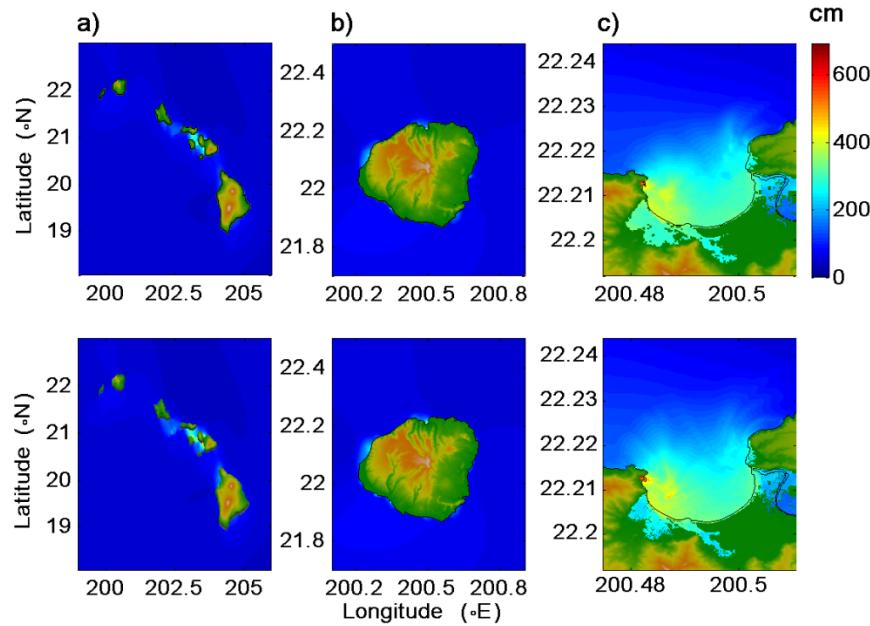


Figure 59. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS101-110 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

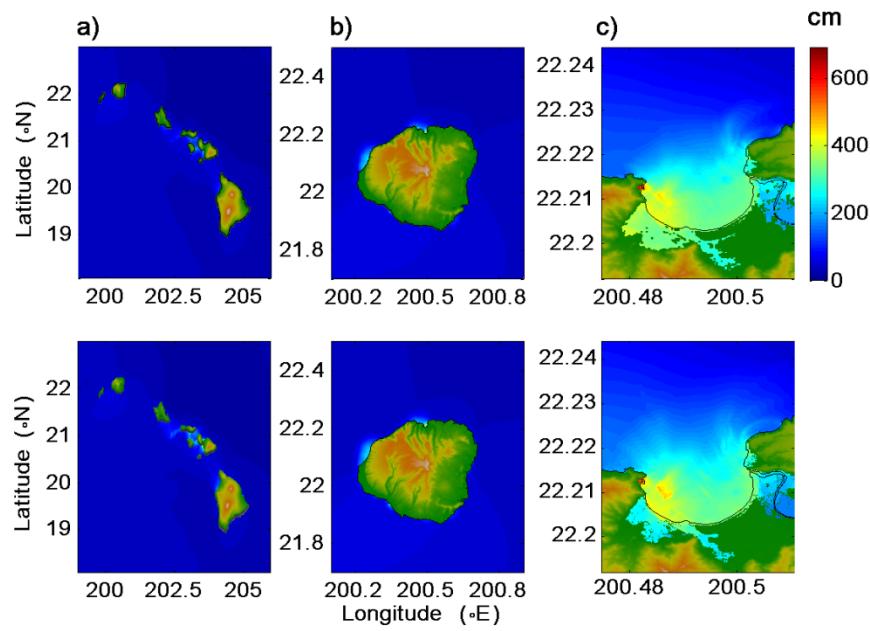


Figure 60. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami CS106-115 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

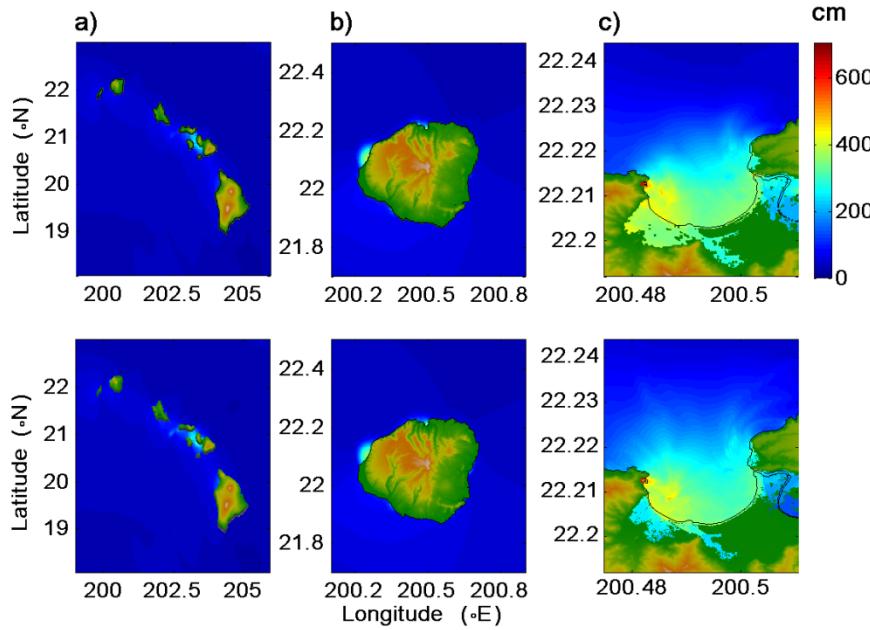


Figure 61. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami EP01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

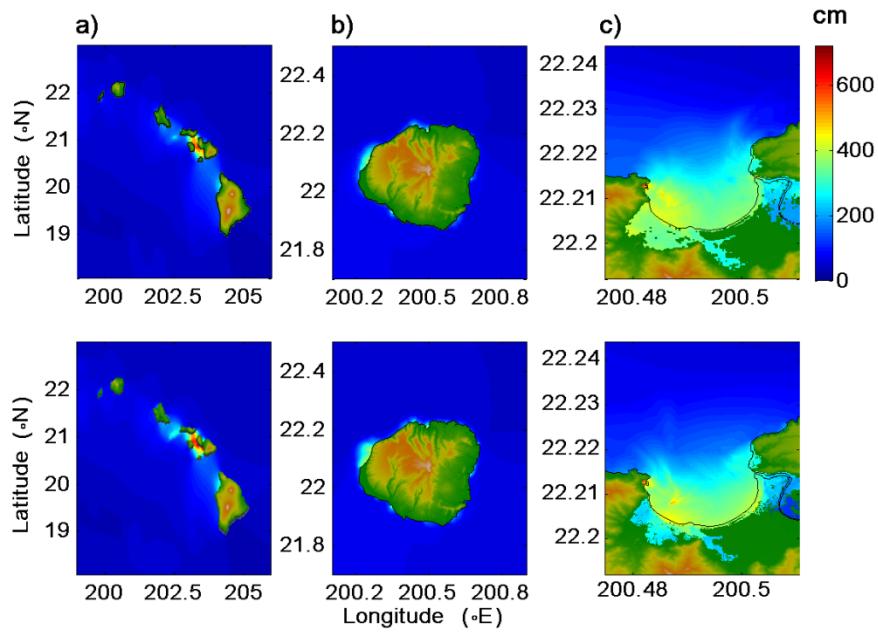


Figure 62. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami EP06-15 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

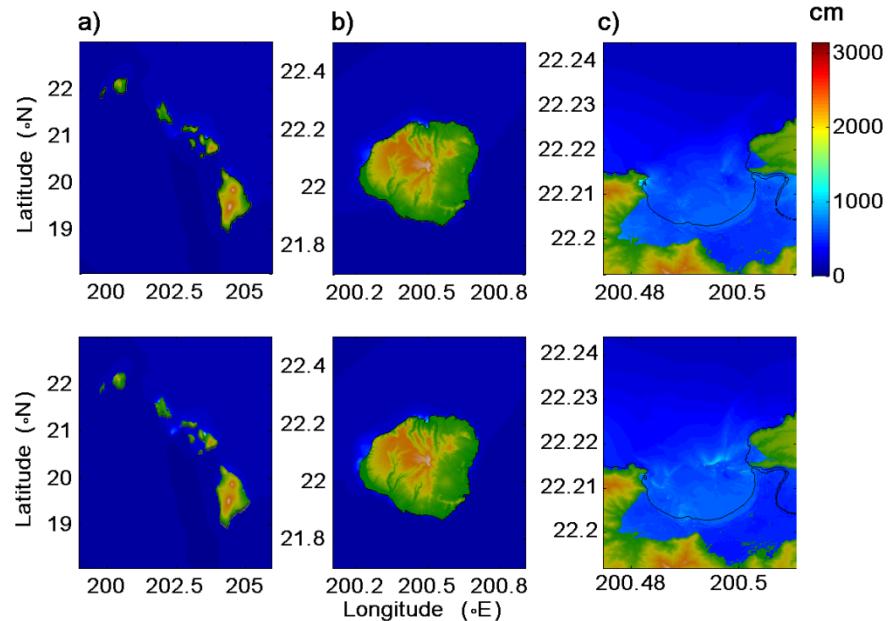


Figure 63. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

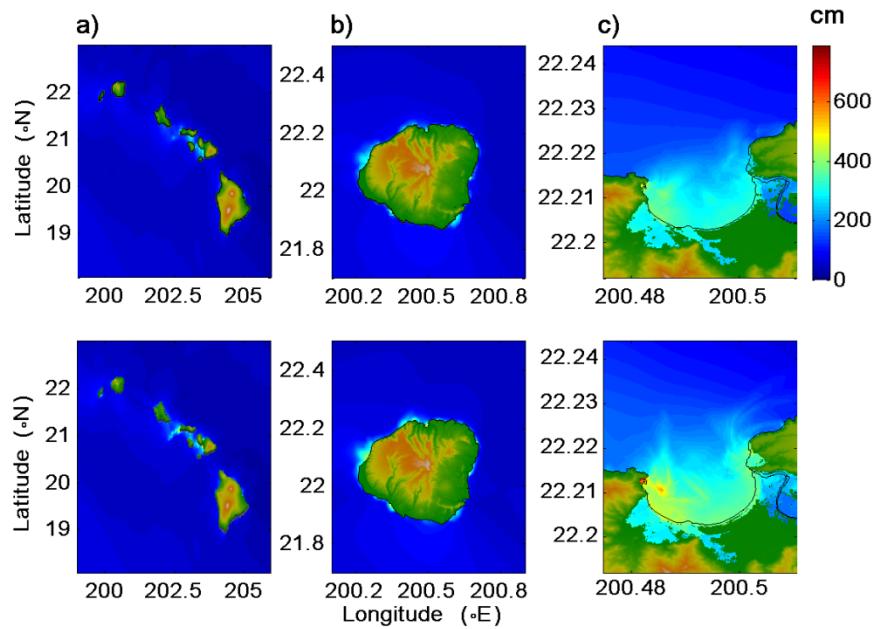


Figure 64. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI11-20 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

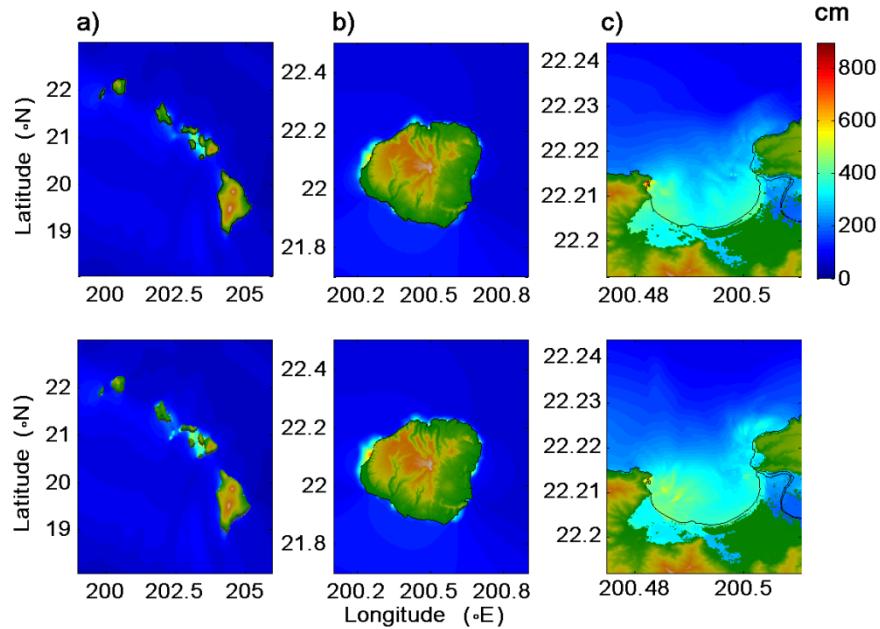


Figure 65. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI22-31 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

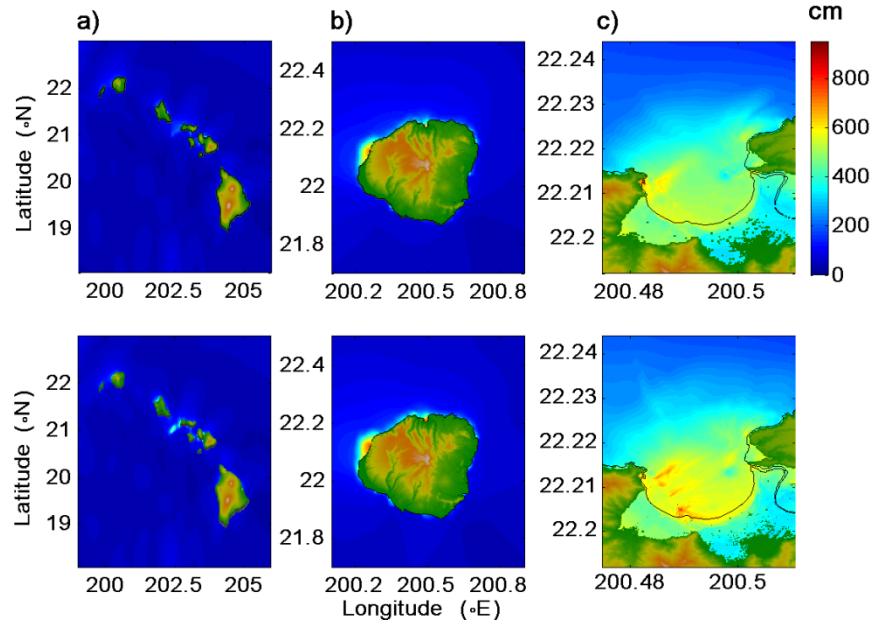


Figure 66. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI32-41 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

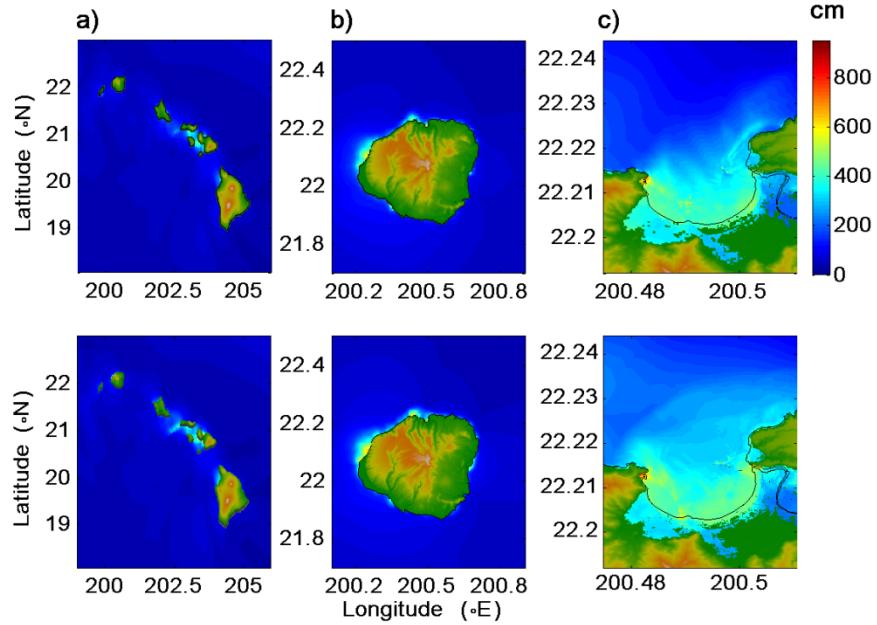


Figure 67. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI42-51 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

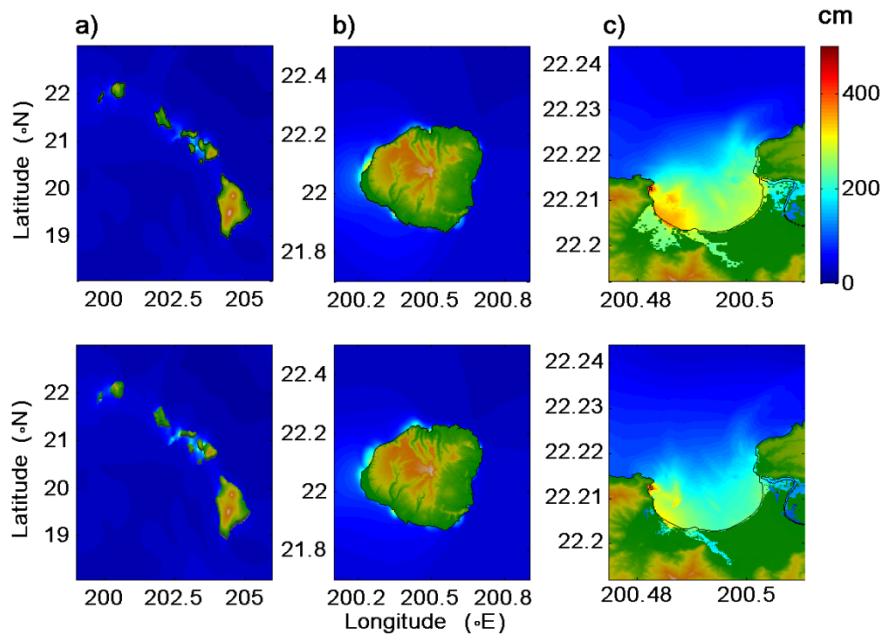


Figure 68. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI52-61 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

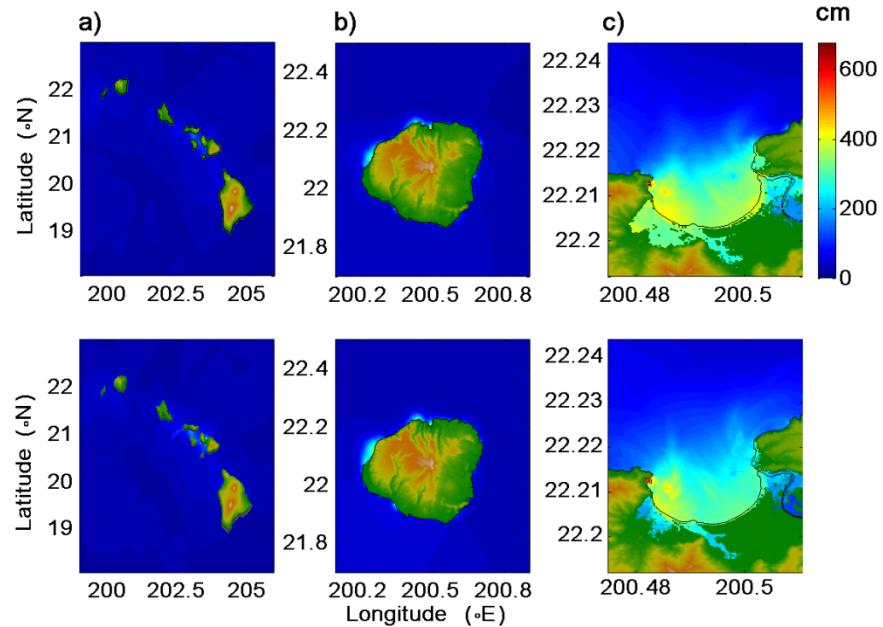


Figure 69. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI56-65 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

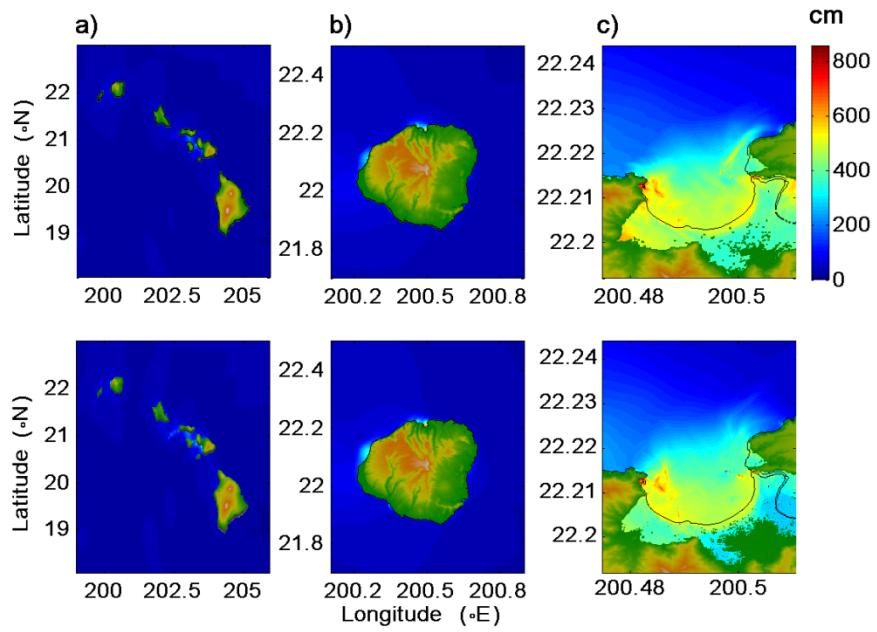


Figure 70. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami KI66-75 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

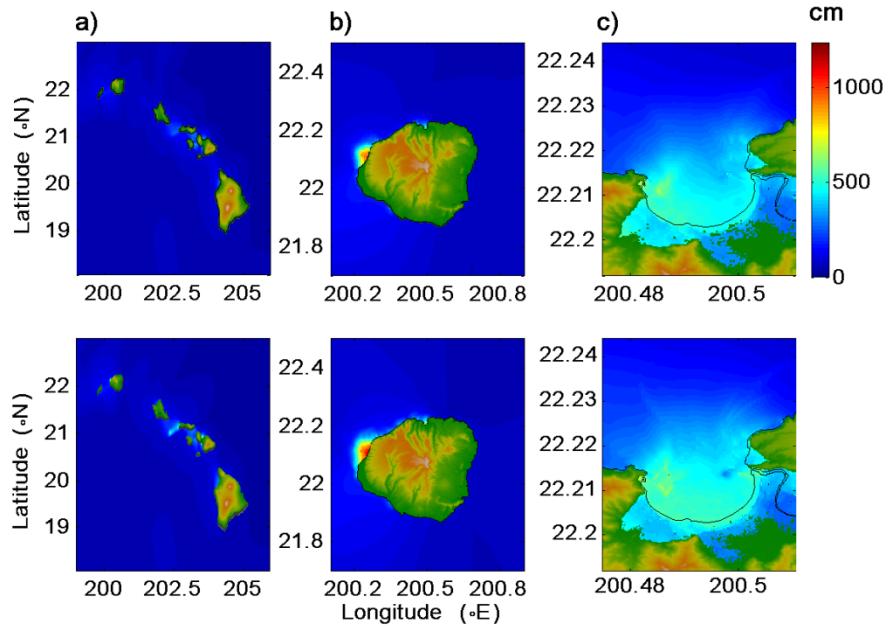


Figure 71. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami MO01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

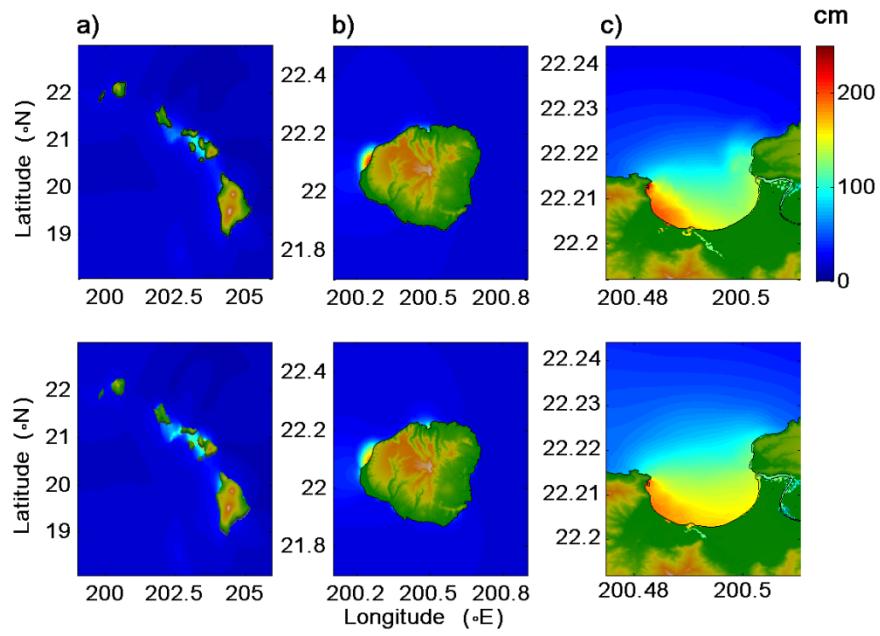


Figure 72. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami MO06-15 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

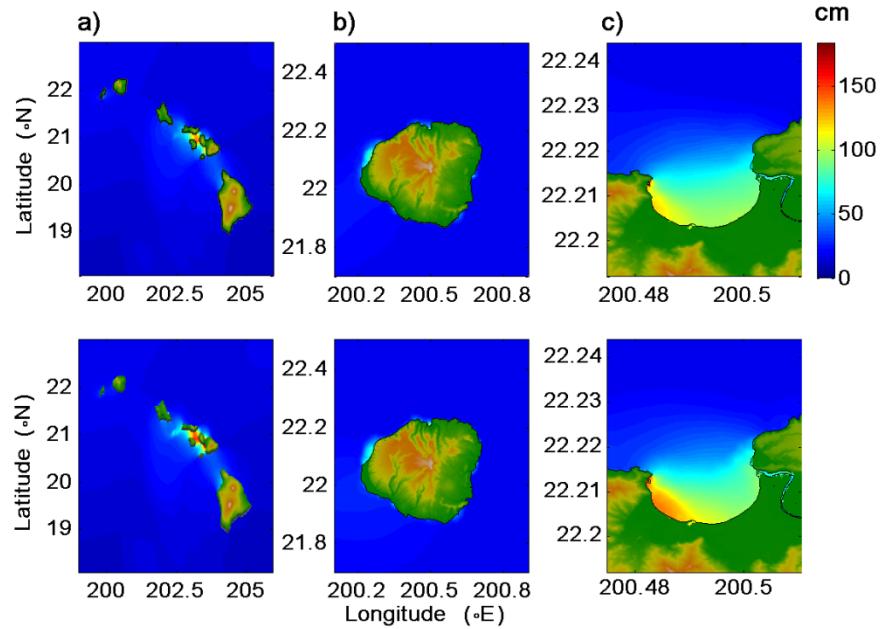


Figure 73. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NG01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

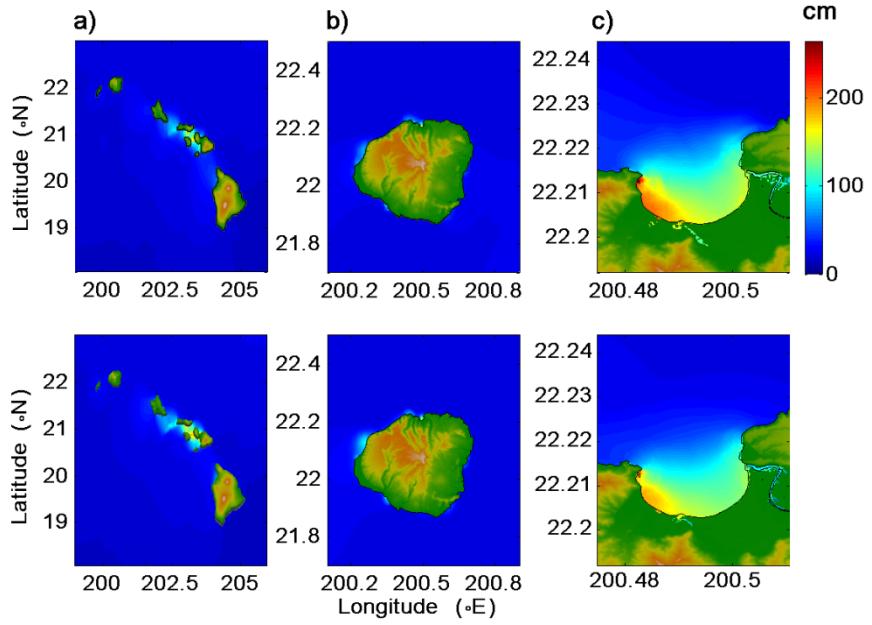


Figure 74. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NG06-15 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

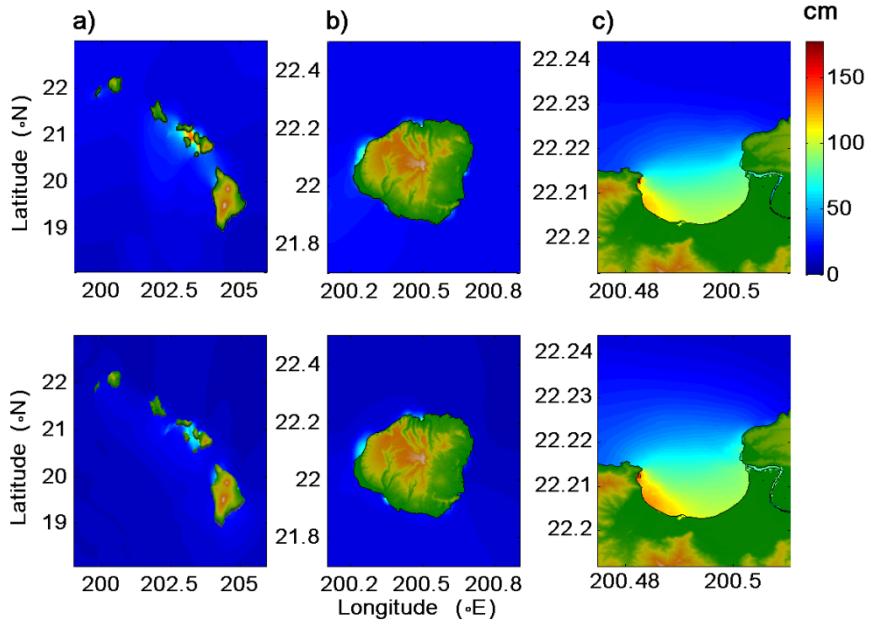


Figure 75. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NT01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

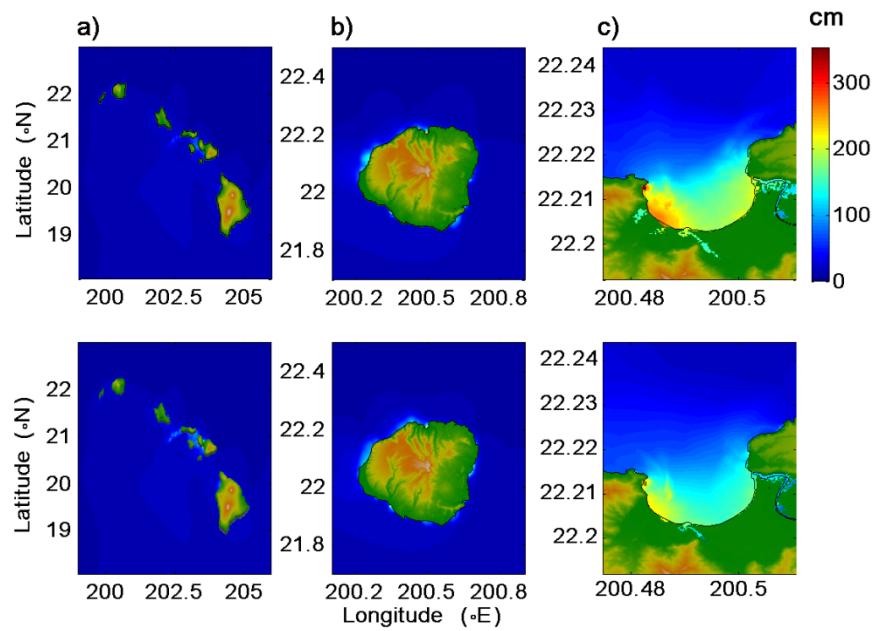


Figure 76. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NT11-20 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

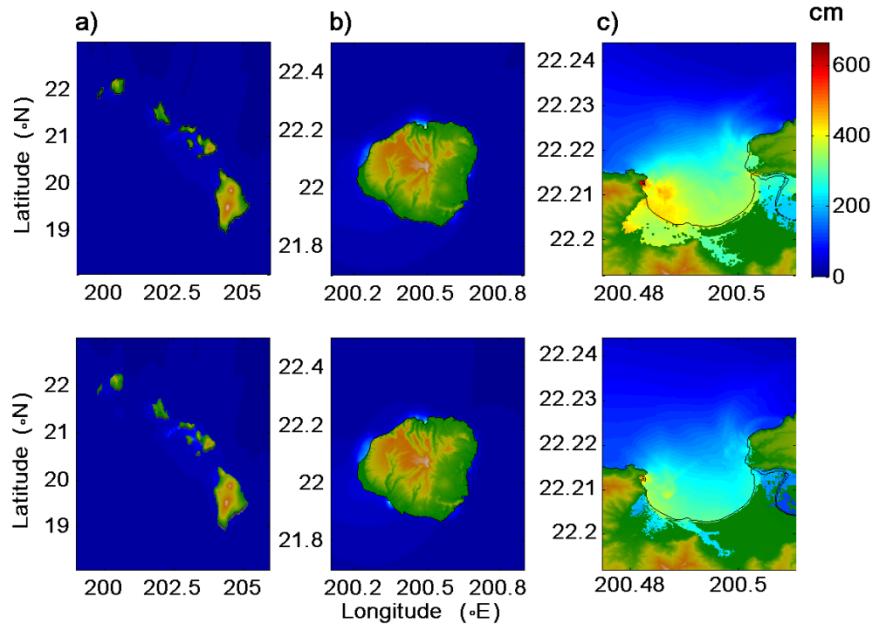


Figure 77. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NT21-30 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

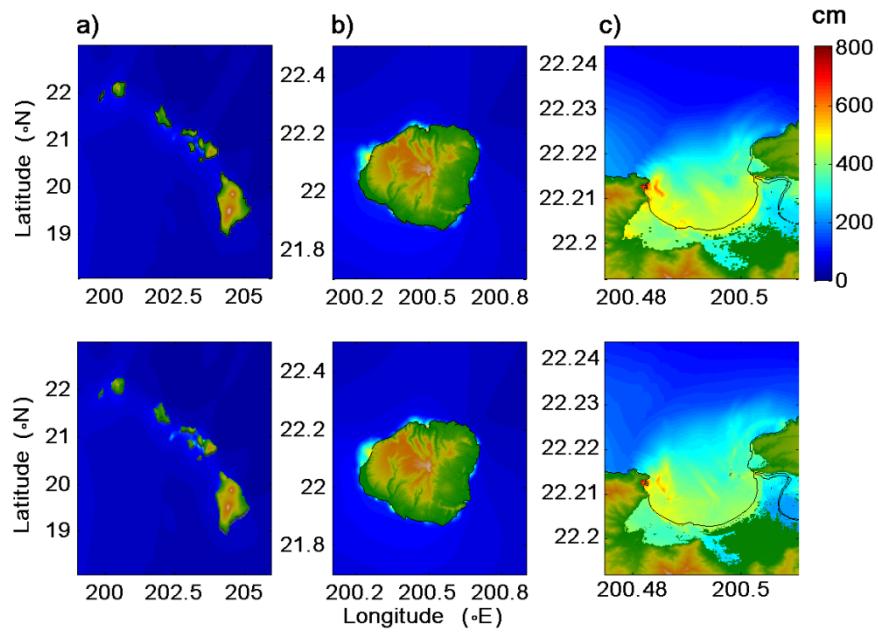


Figure 78. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NT30-39 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

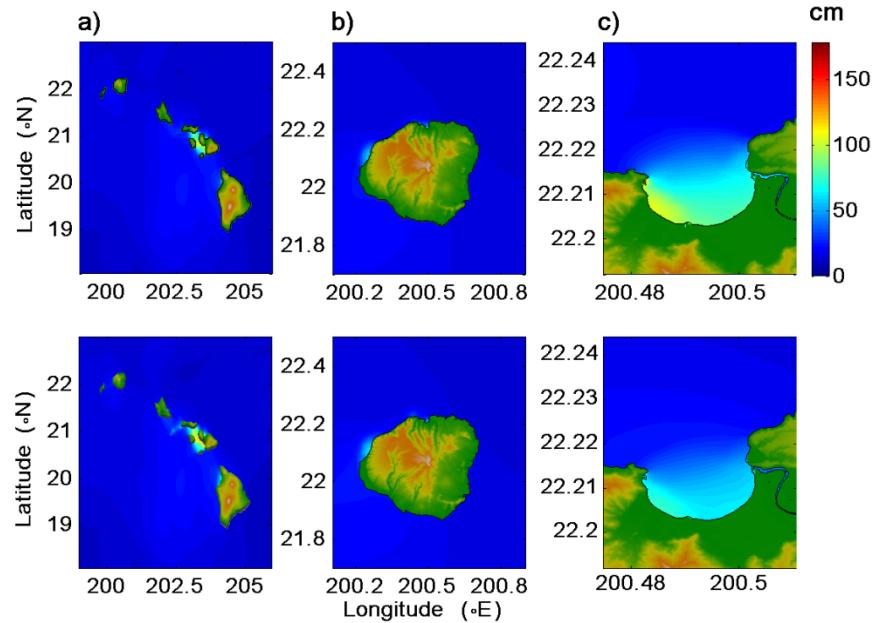


Figure 79. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NV01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

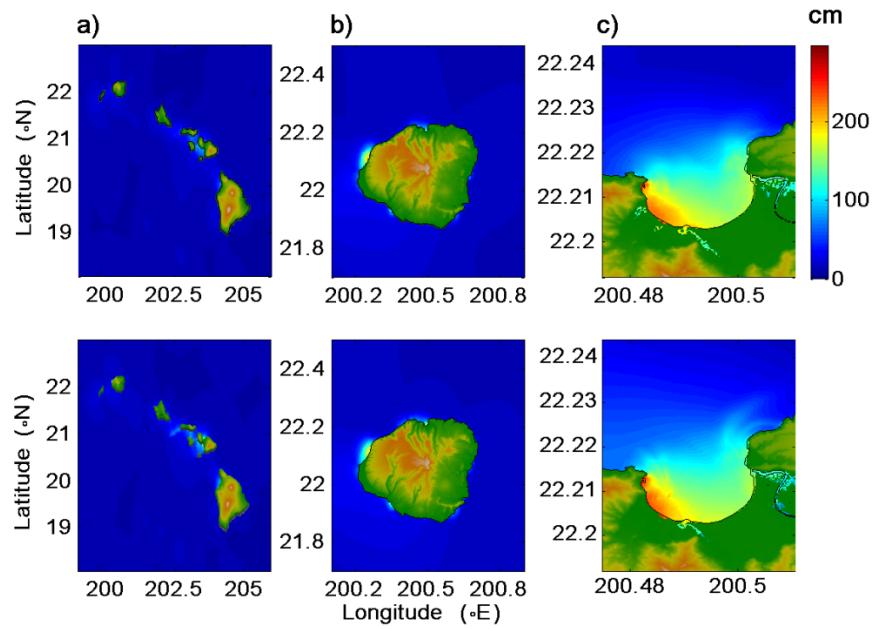


Figure 80. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NV11-20 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

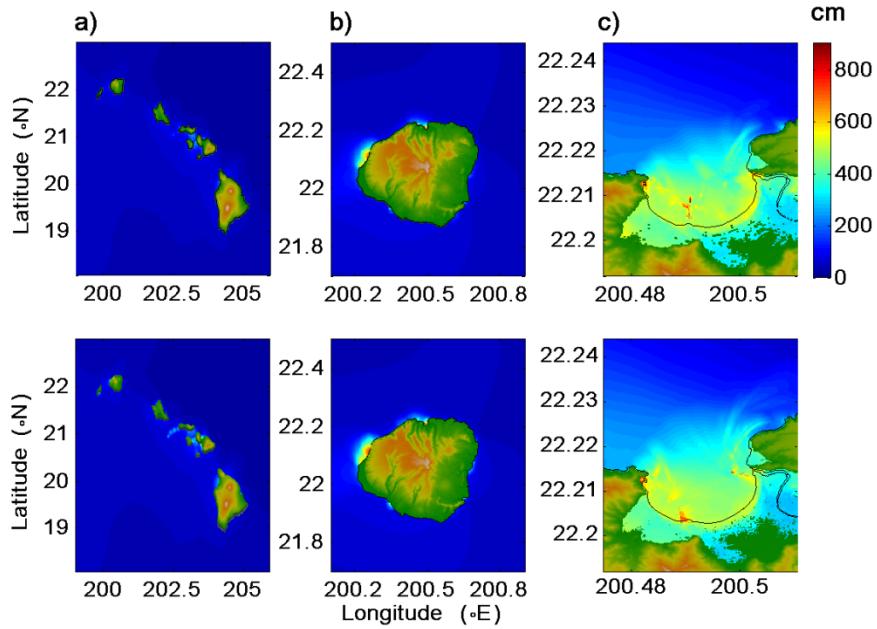


Figure 81. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami NV28-37 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

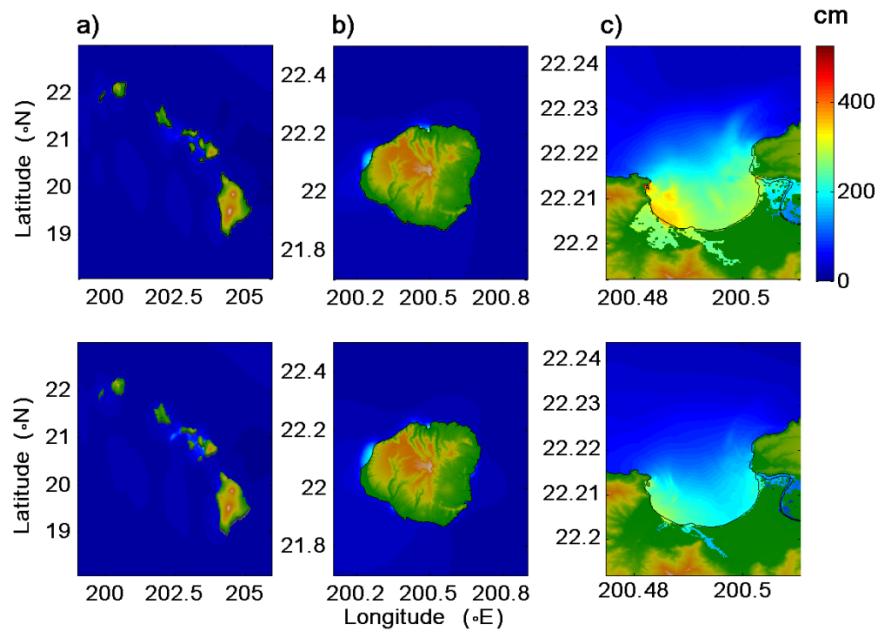


Figure 82. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami RN01-10 for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

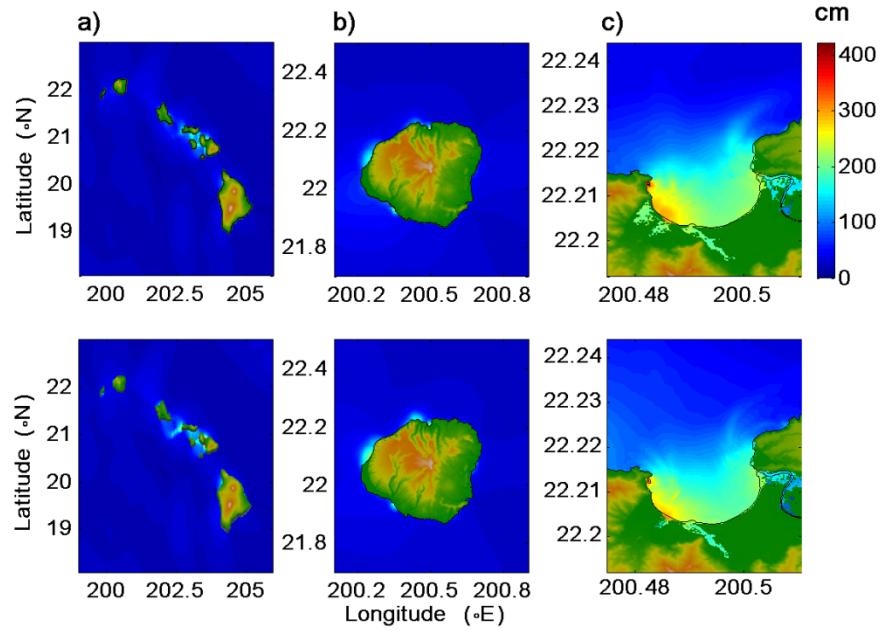


Figure 83. Maximum tsunami wave amplitude distribution of synthetic mega-event tsunami RN13-22AB for A, B and C-grids; forecast model (upper figures) and reference model (lower figures).

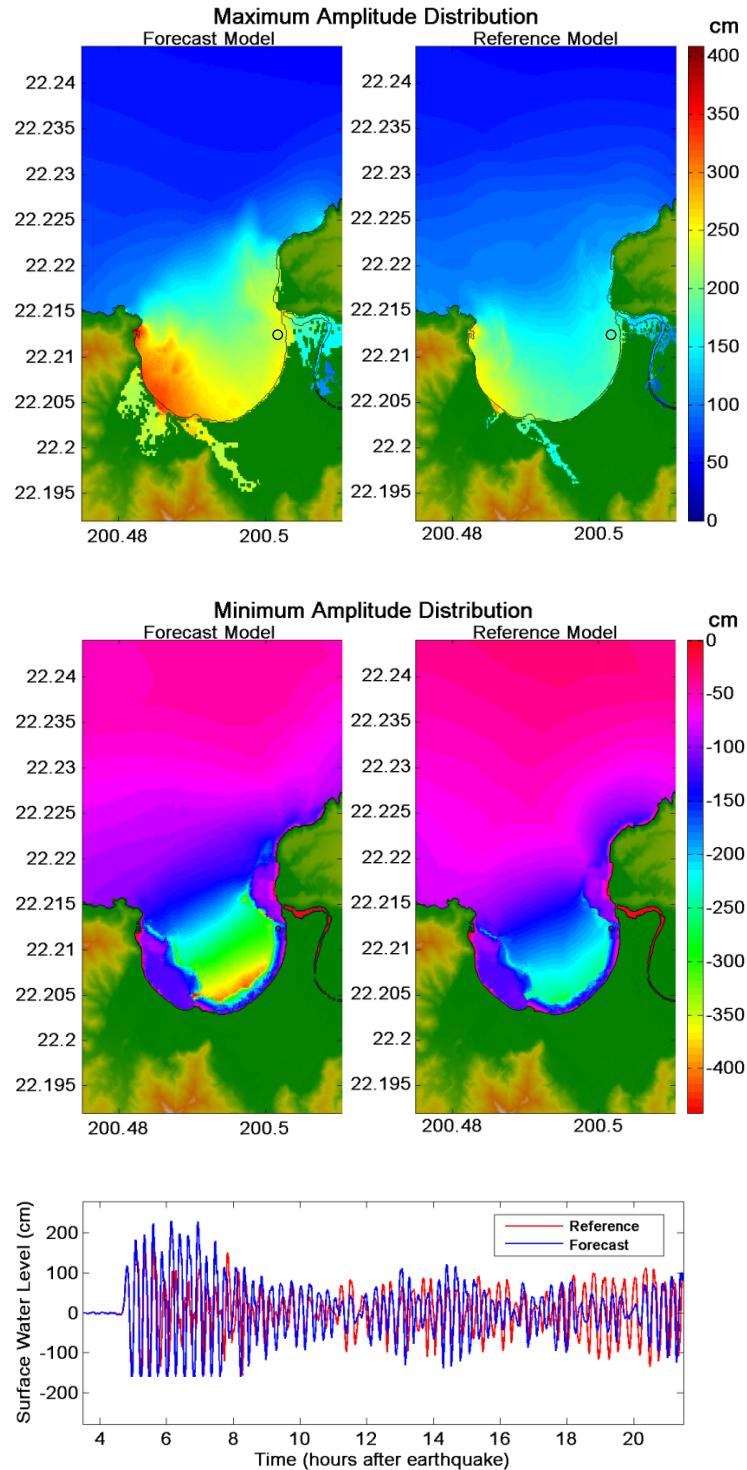


Figure 84. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event AC01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

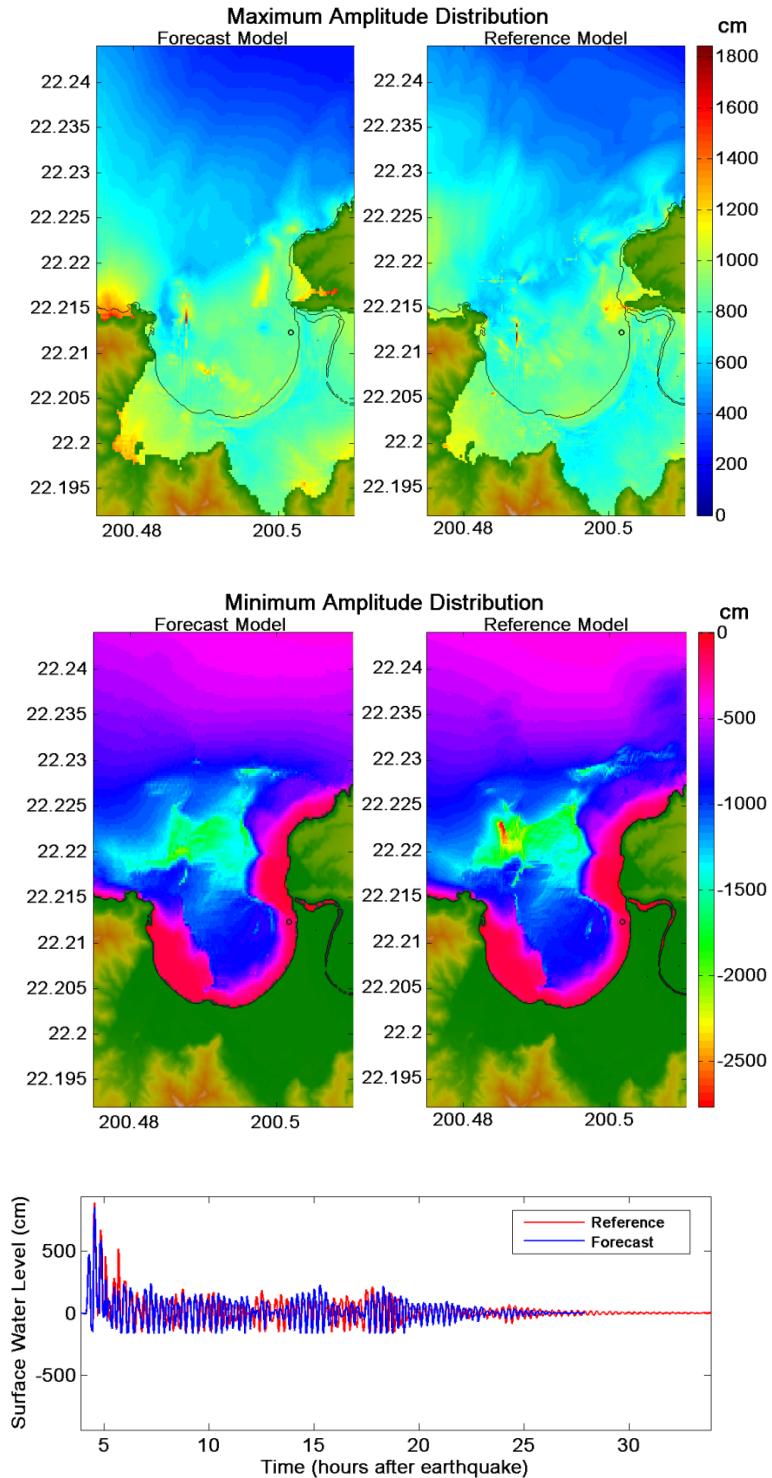


Figure 85. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event AC11-20; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

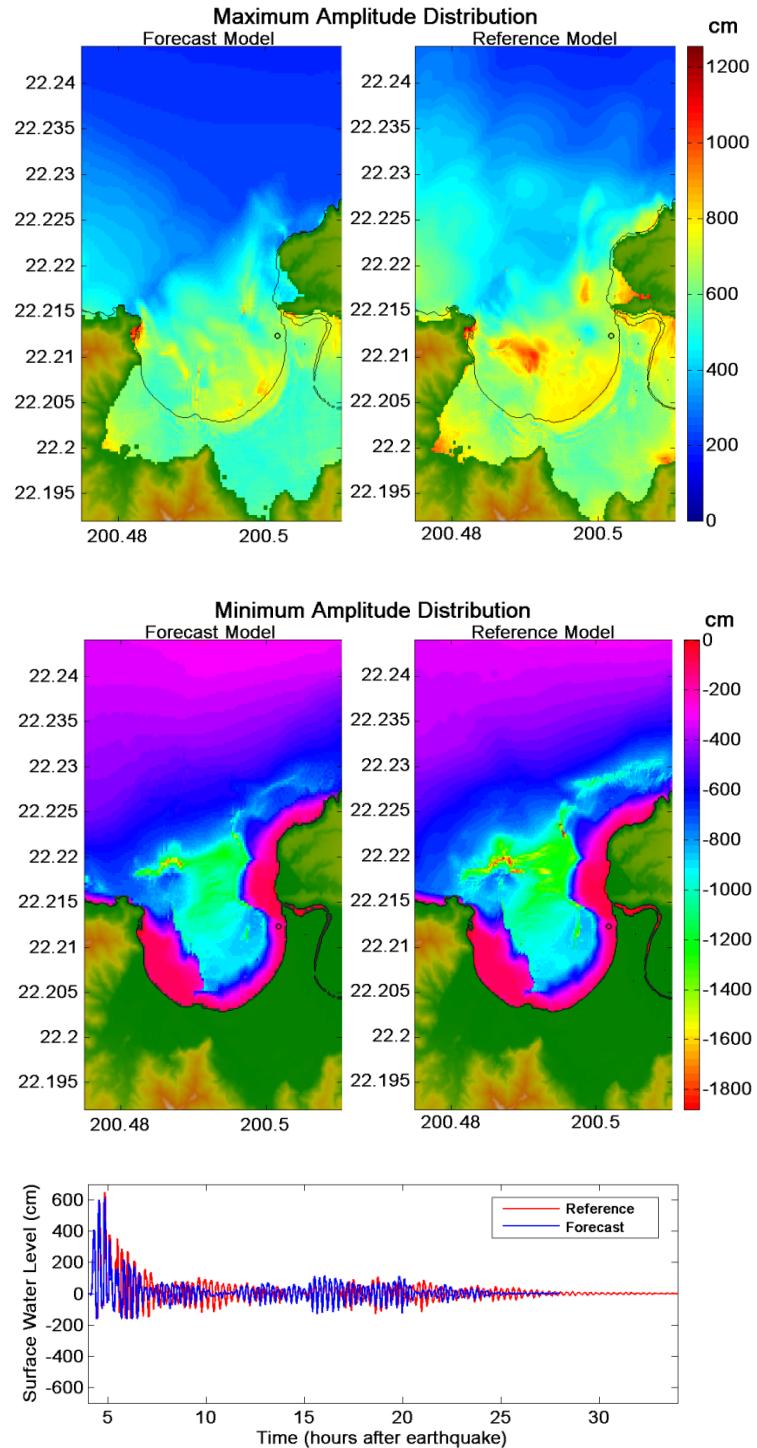


Figure 86. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event AC21-30; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

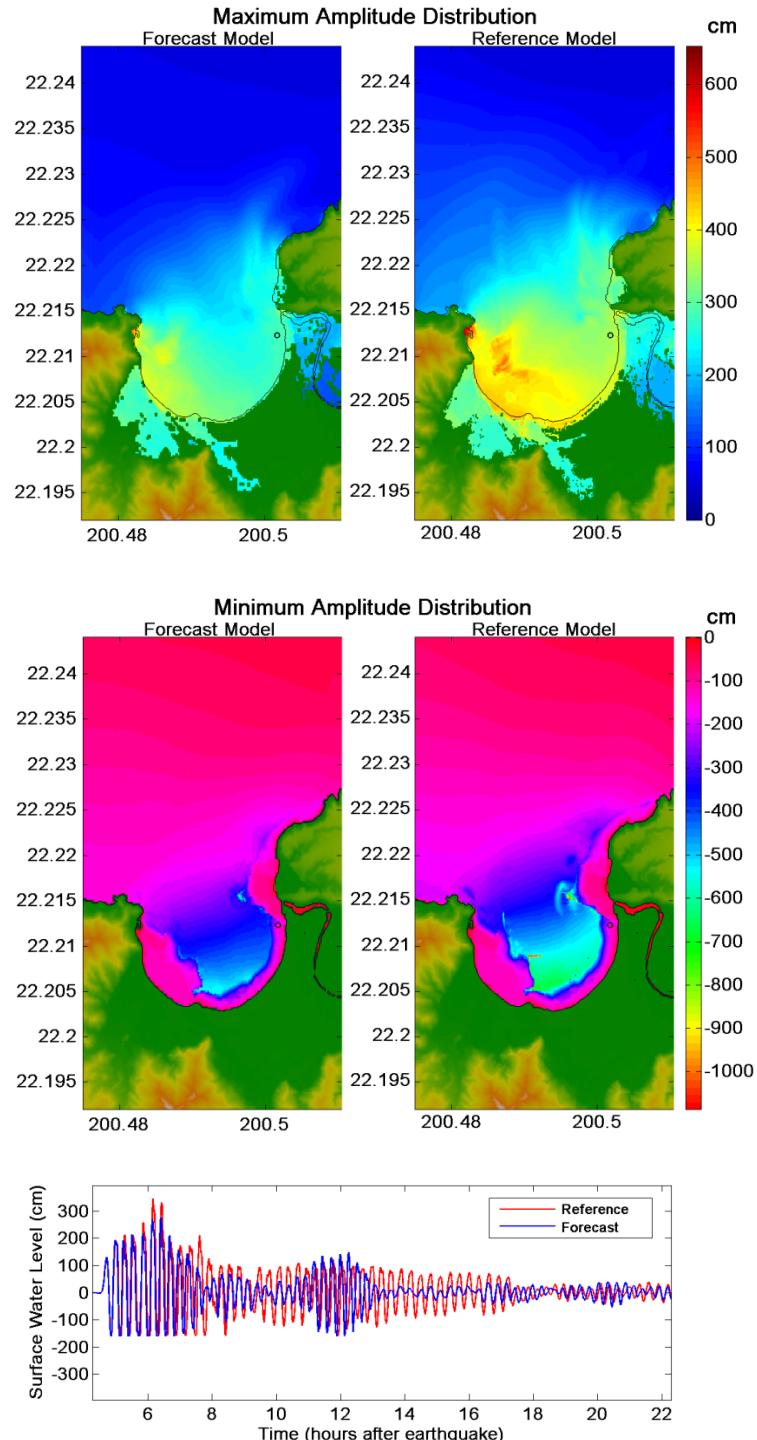


Figure 87. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event AC31-40; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

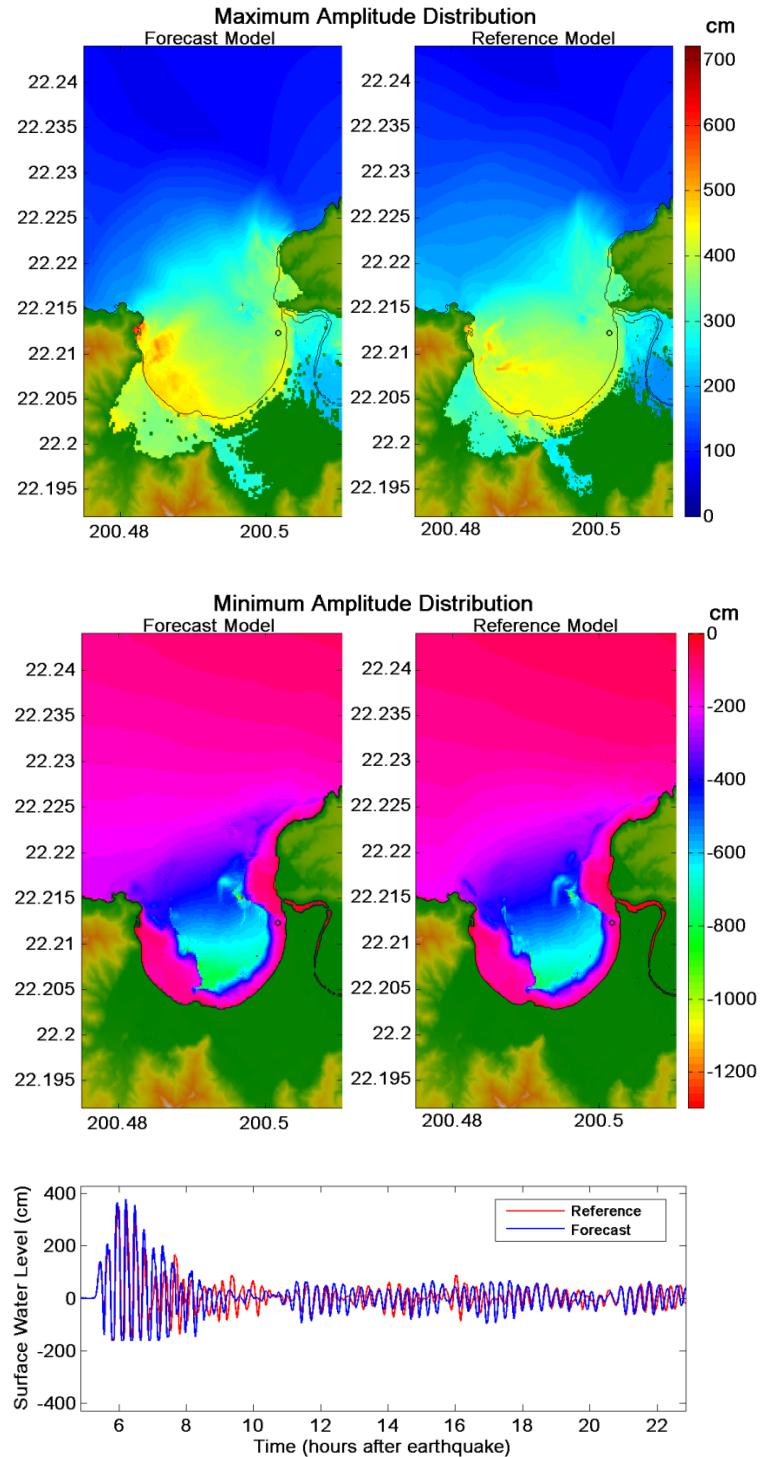


Figure 88. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event AC41-50; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

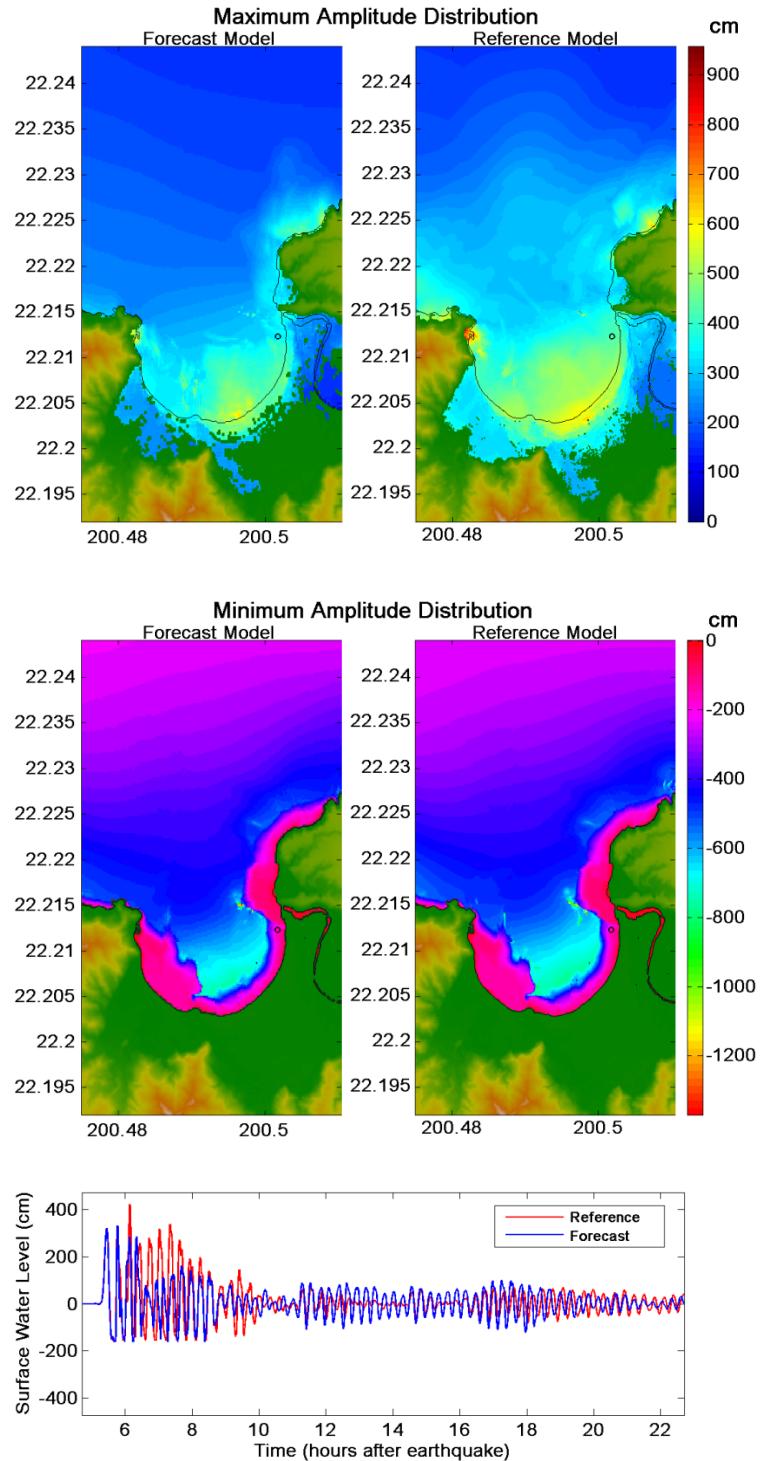


Figure 89. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event AC51-60; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

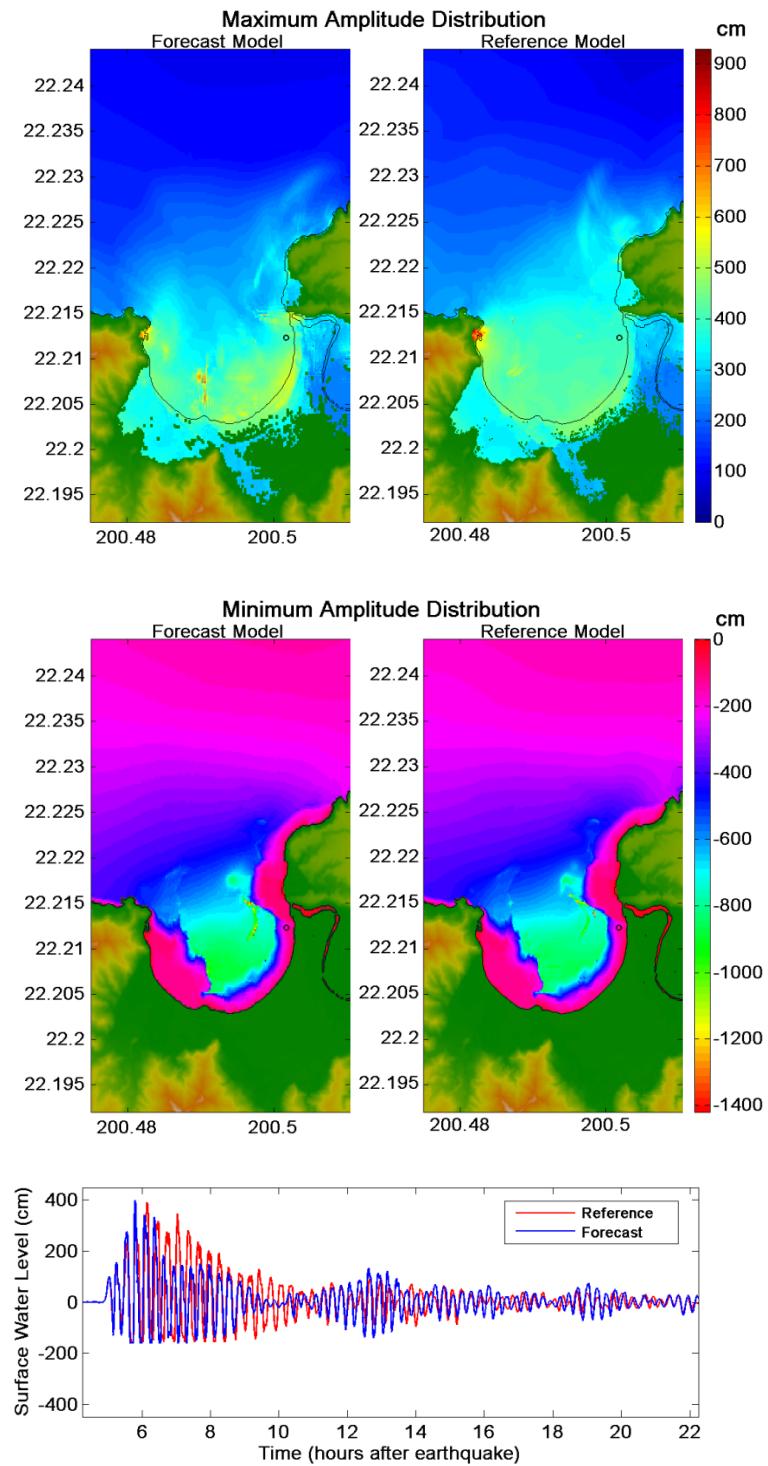


Figure 90. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event AC56-65; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

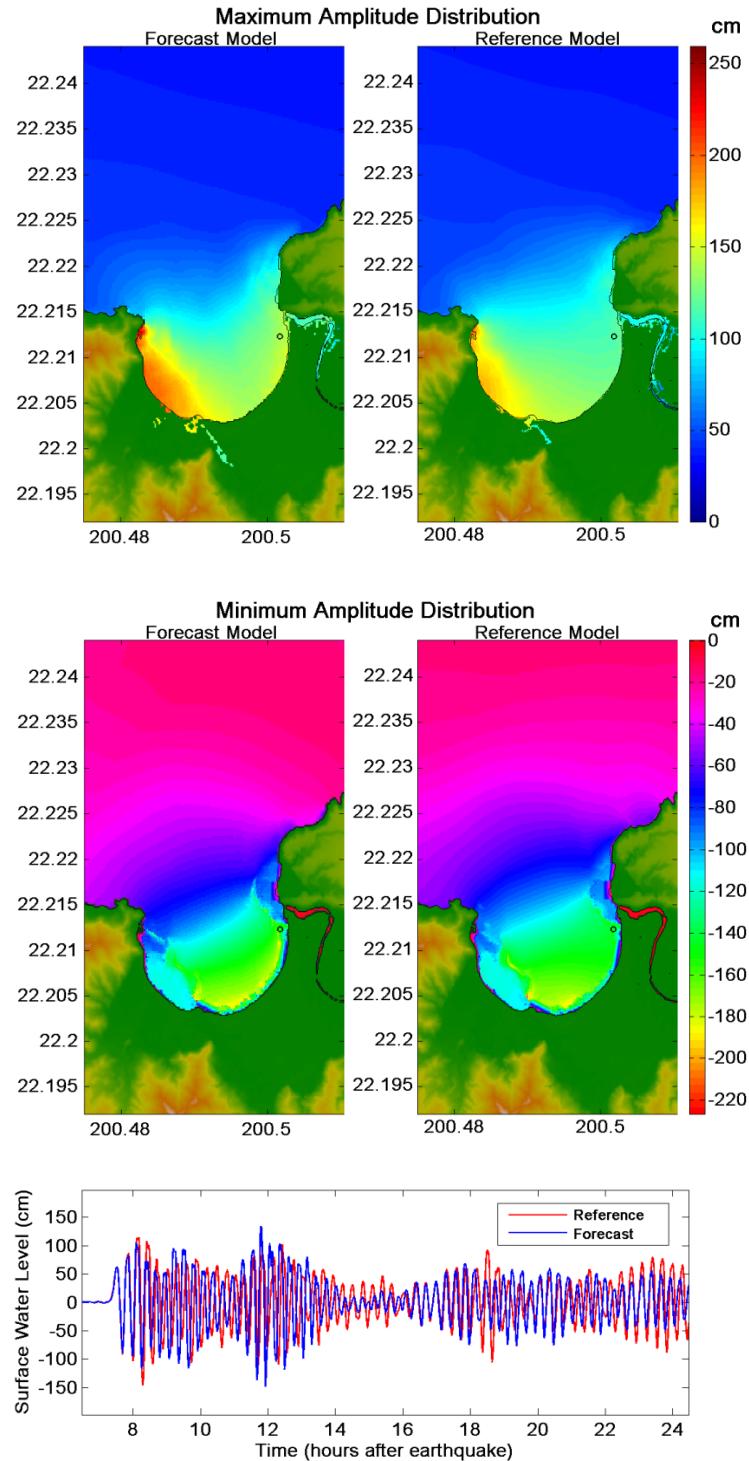


Figure 91. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

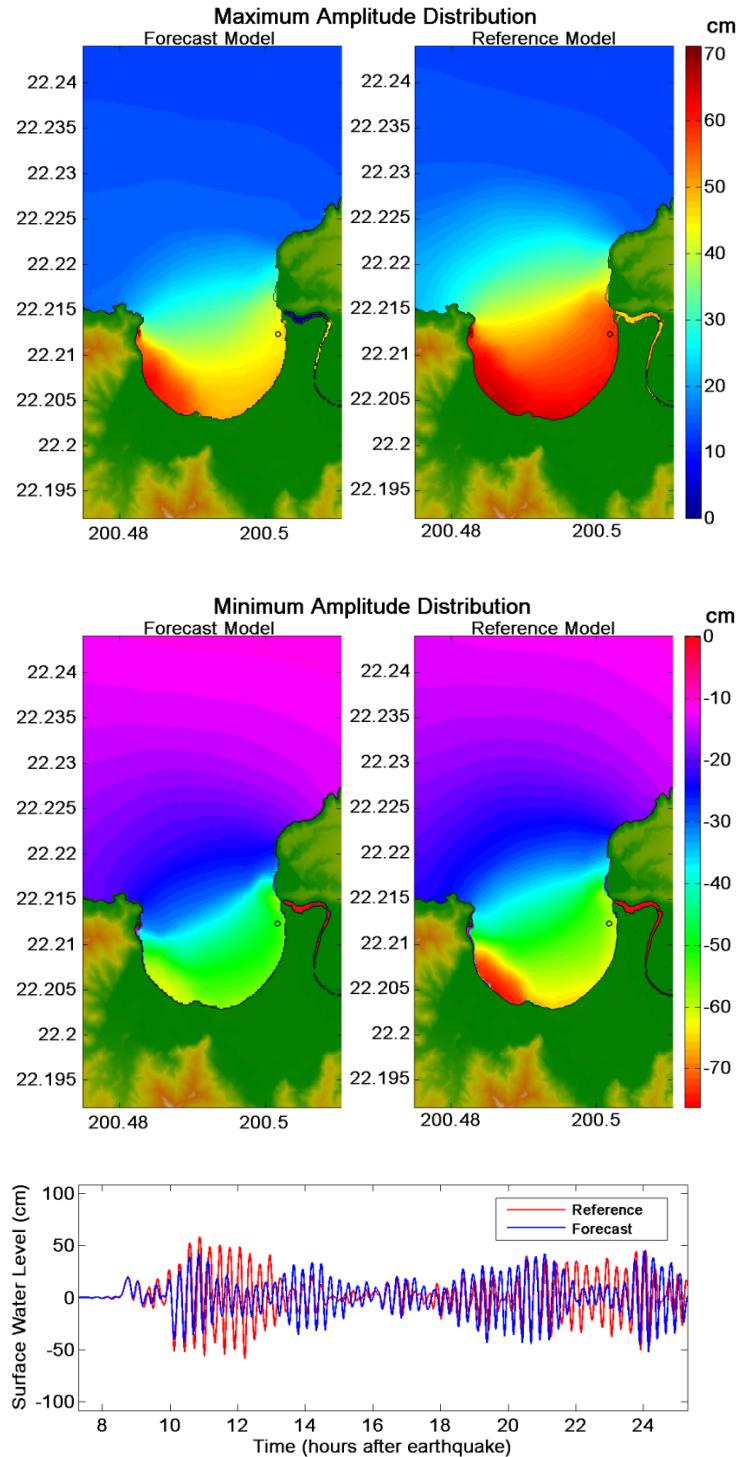


Figure 92. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS11-20; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

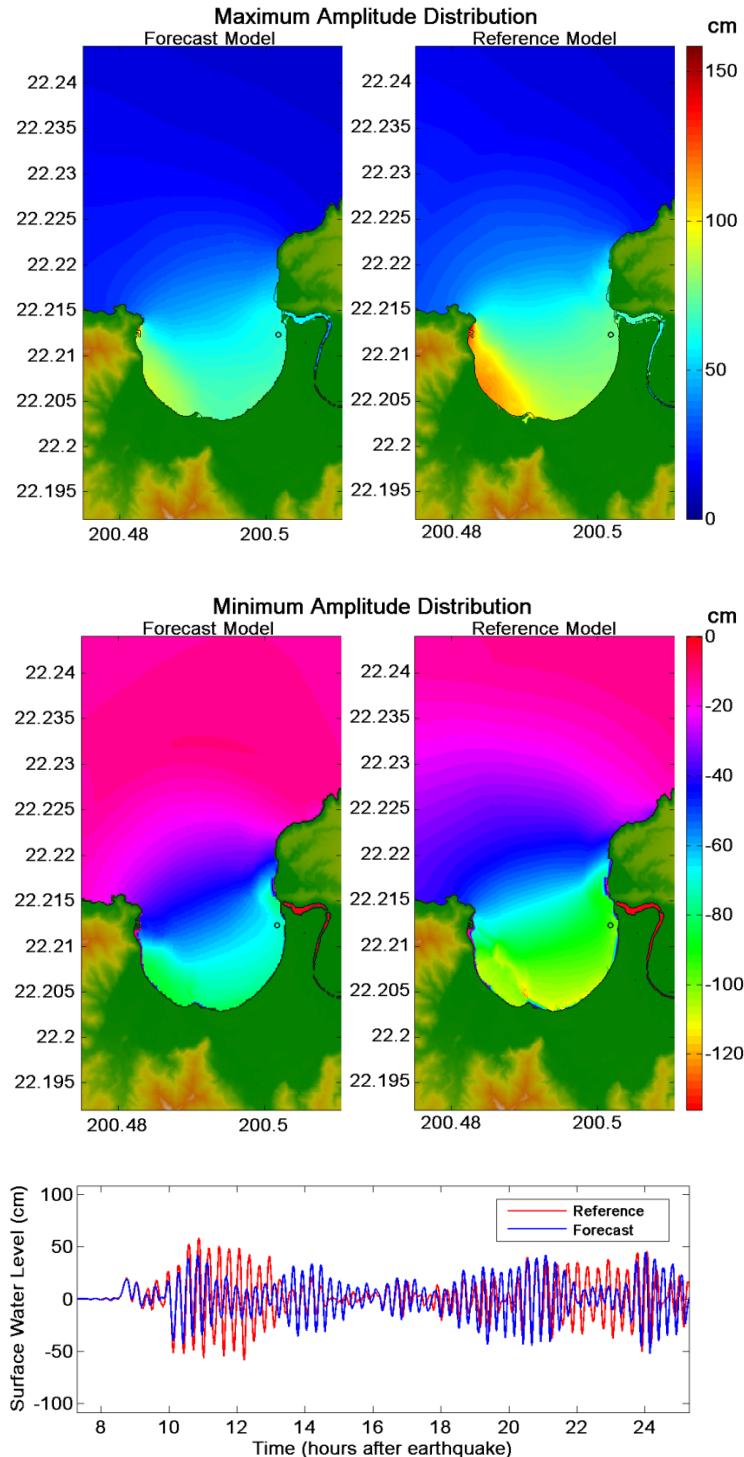


Figure 93. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS21-30; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

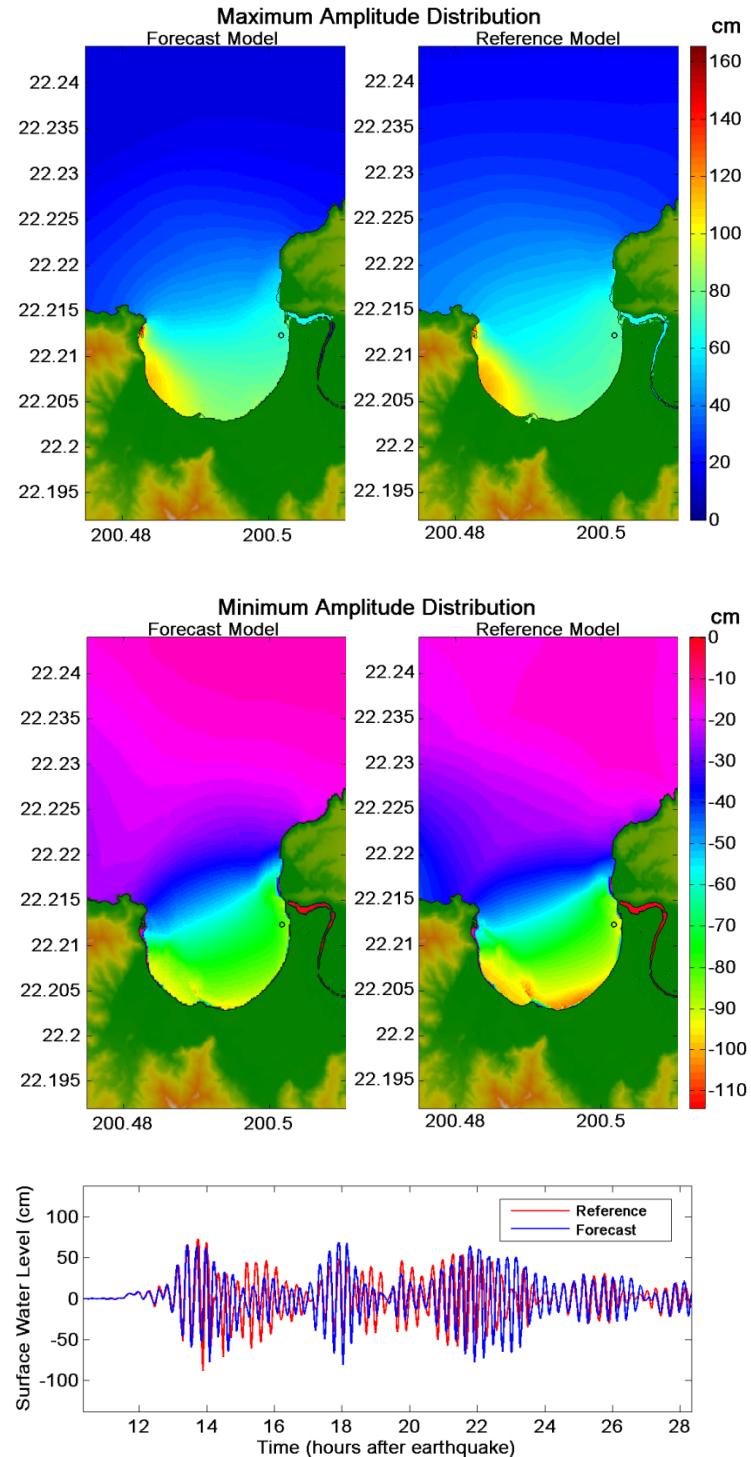


Figure 94. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS31-40; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

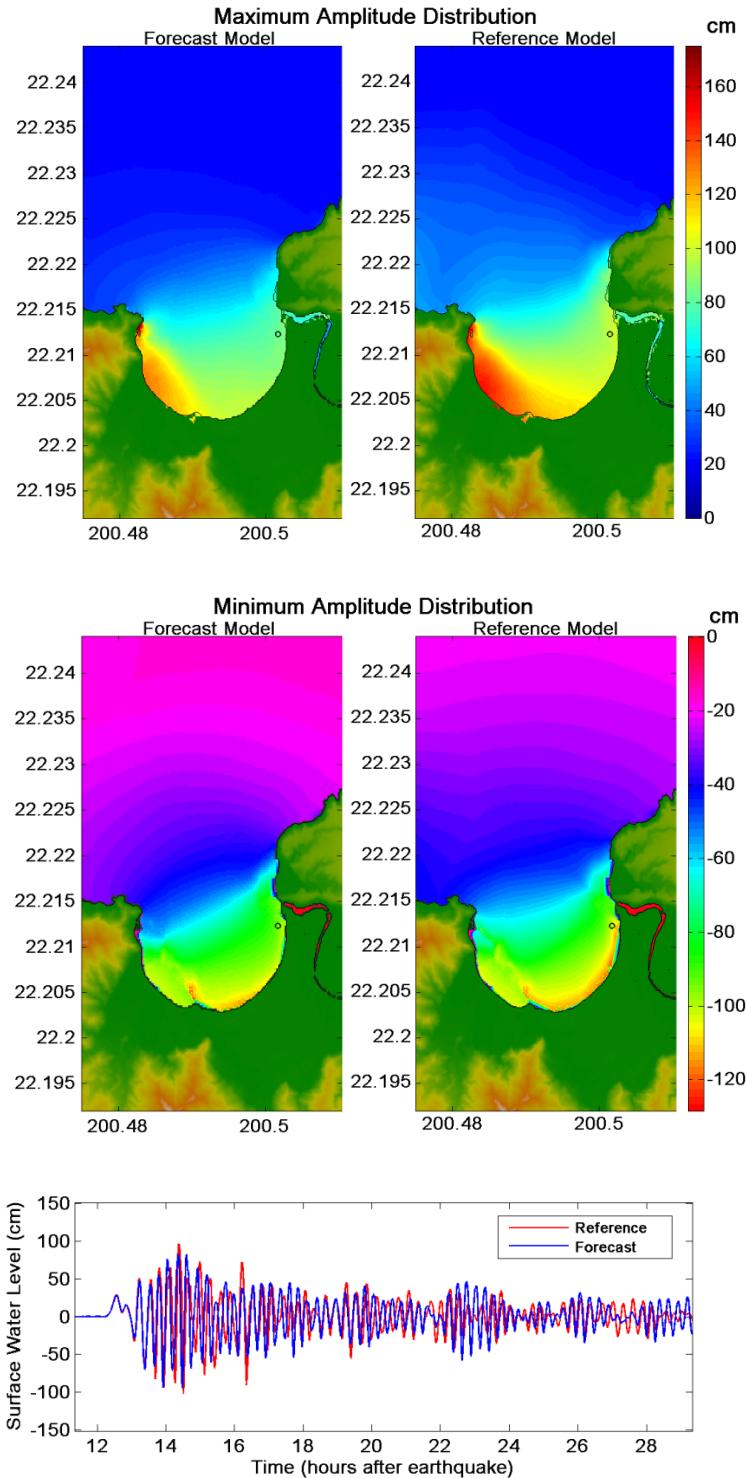


Figure 95. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS41-50; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

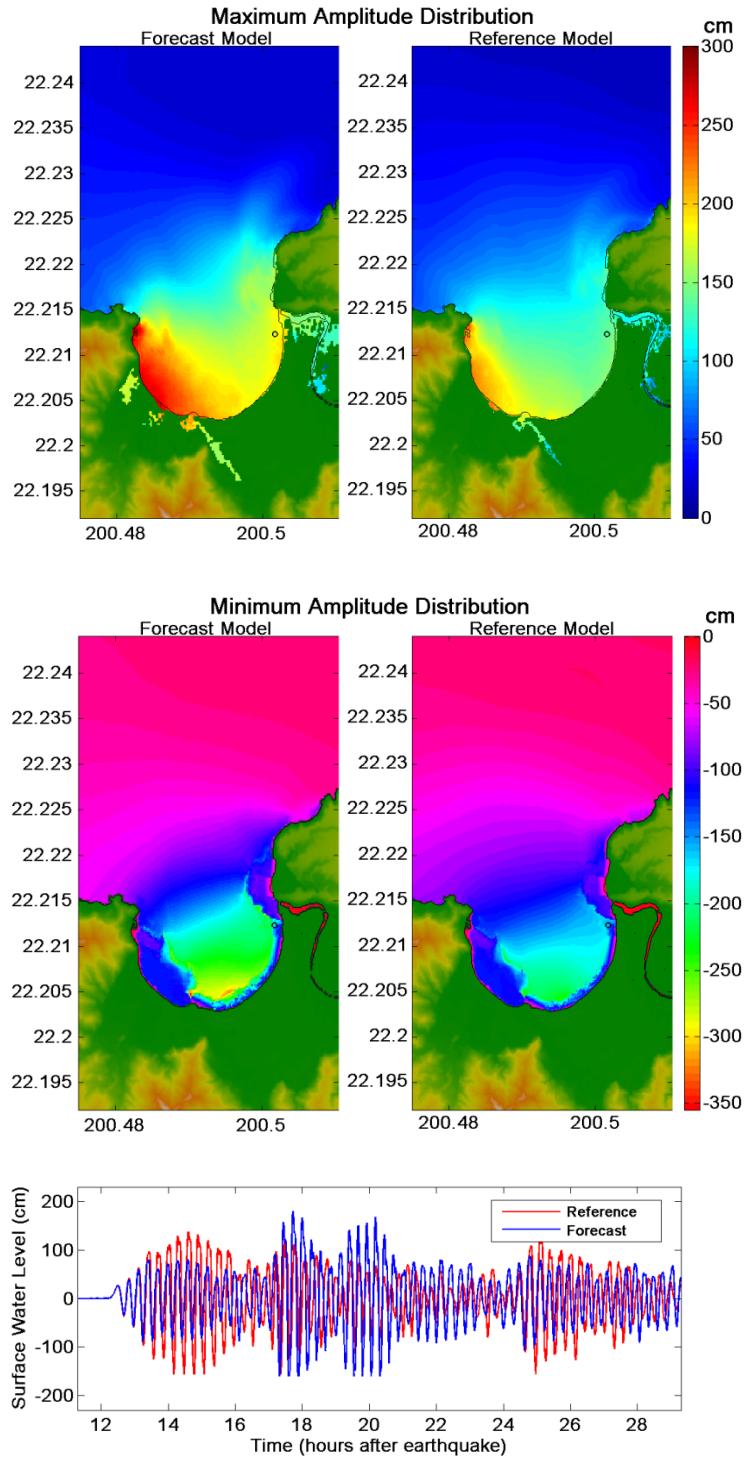


Figure 96. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS51-60; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

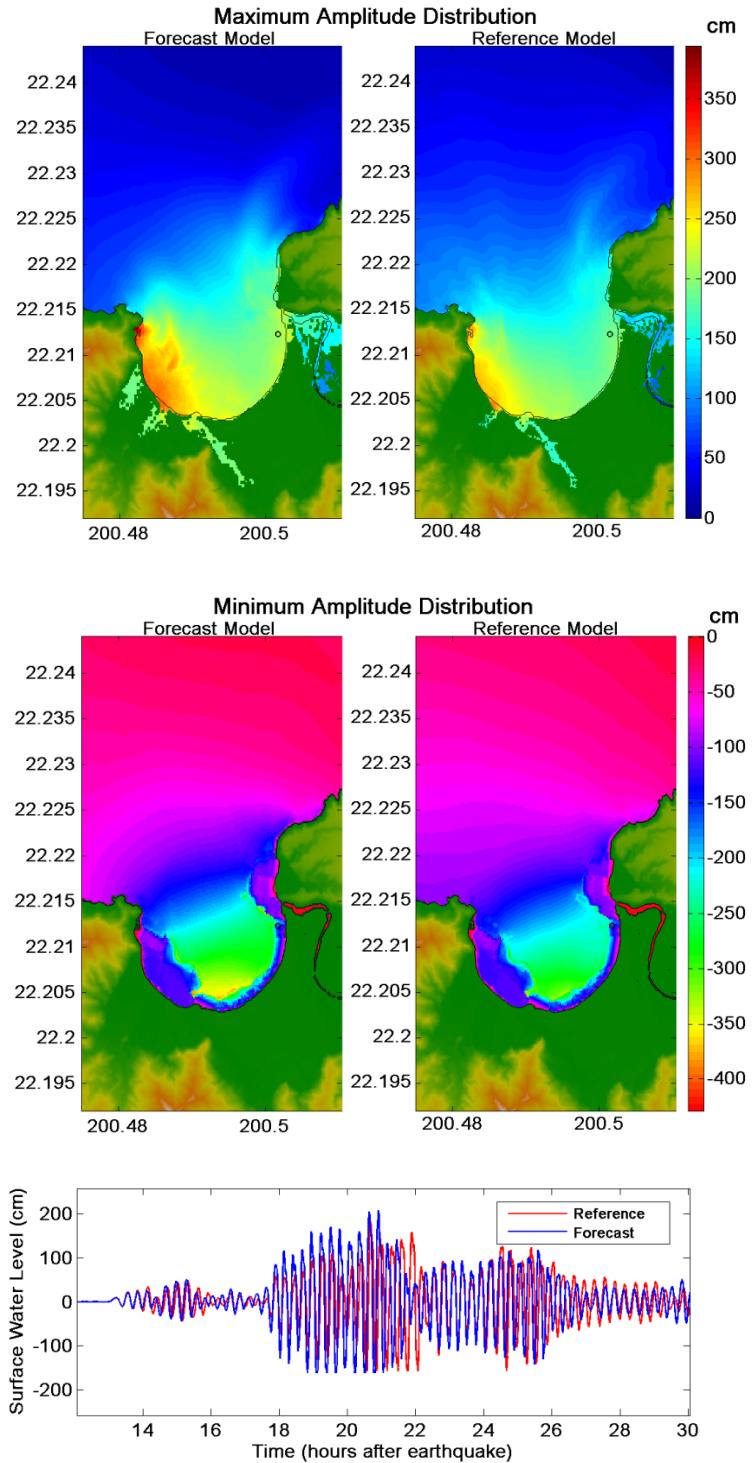


Figure 97. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS61-70; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

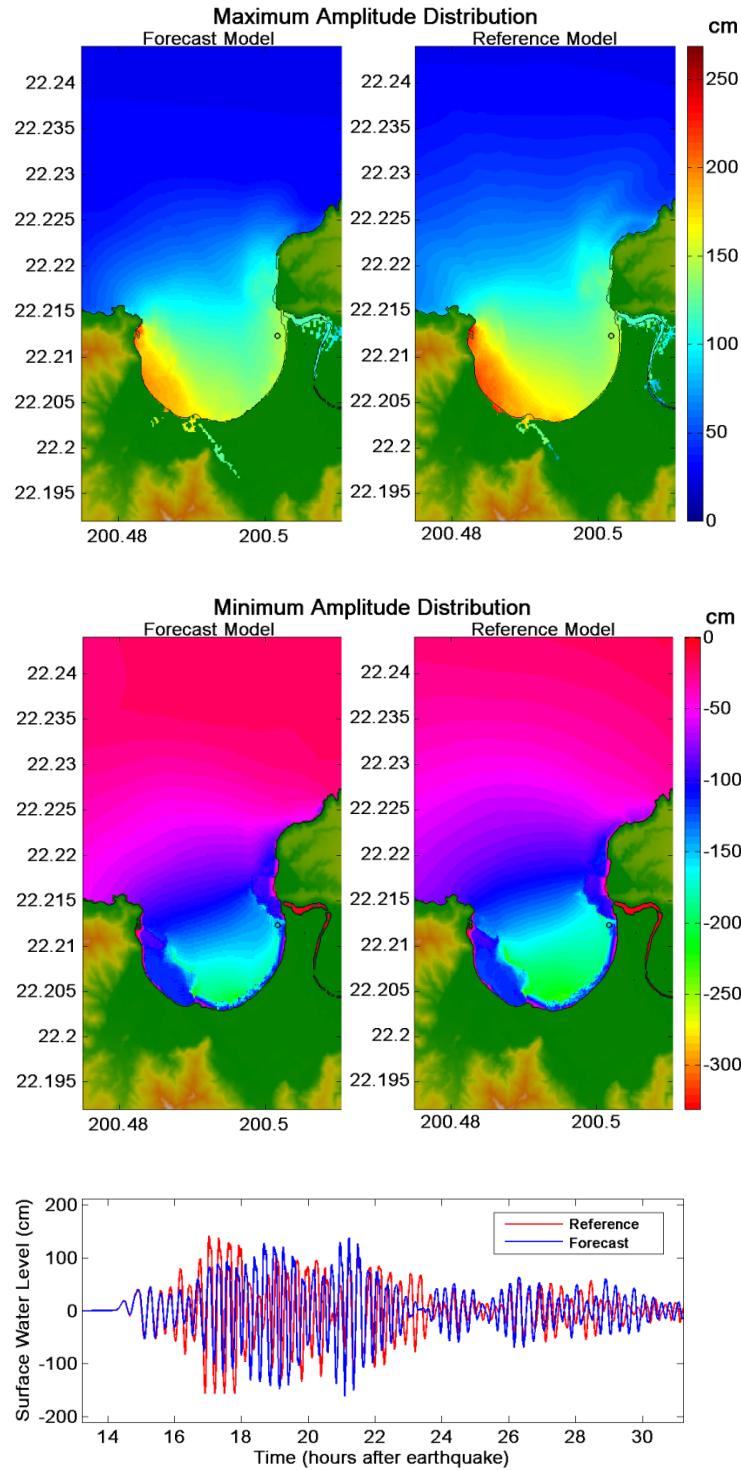


Figure 98. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS71-80; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

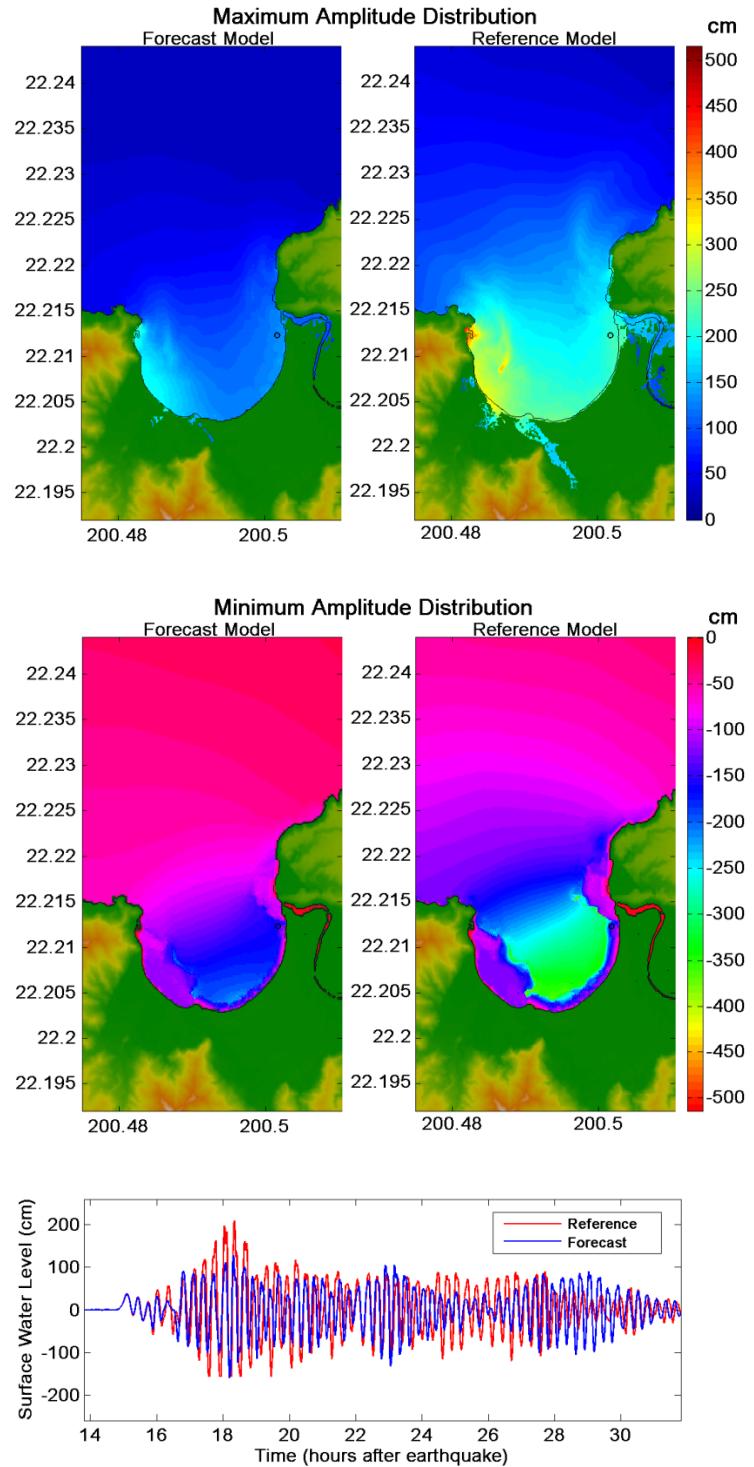


Figure 99. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event C81-90; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

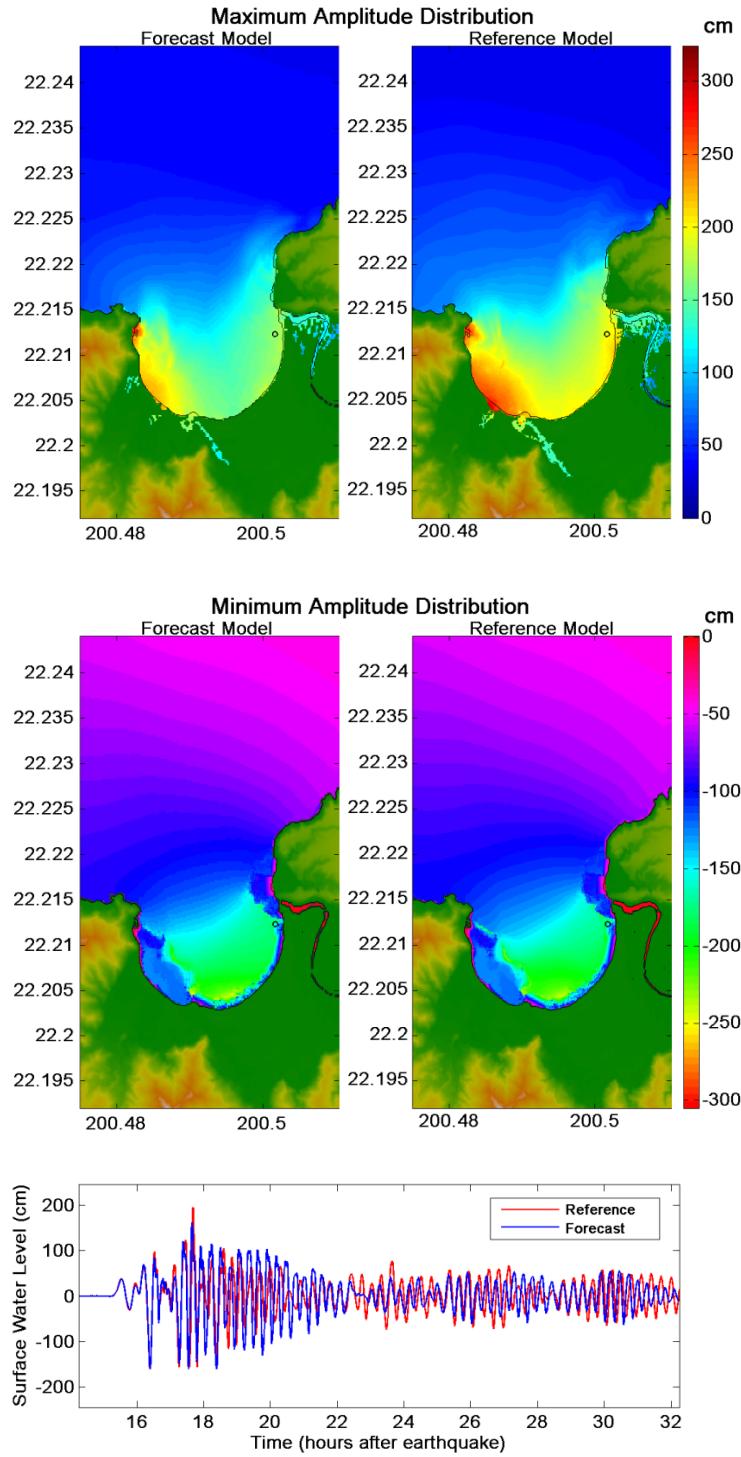


Figure 100. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS91-100; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

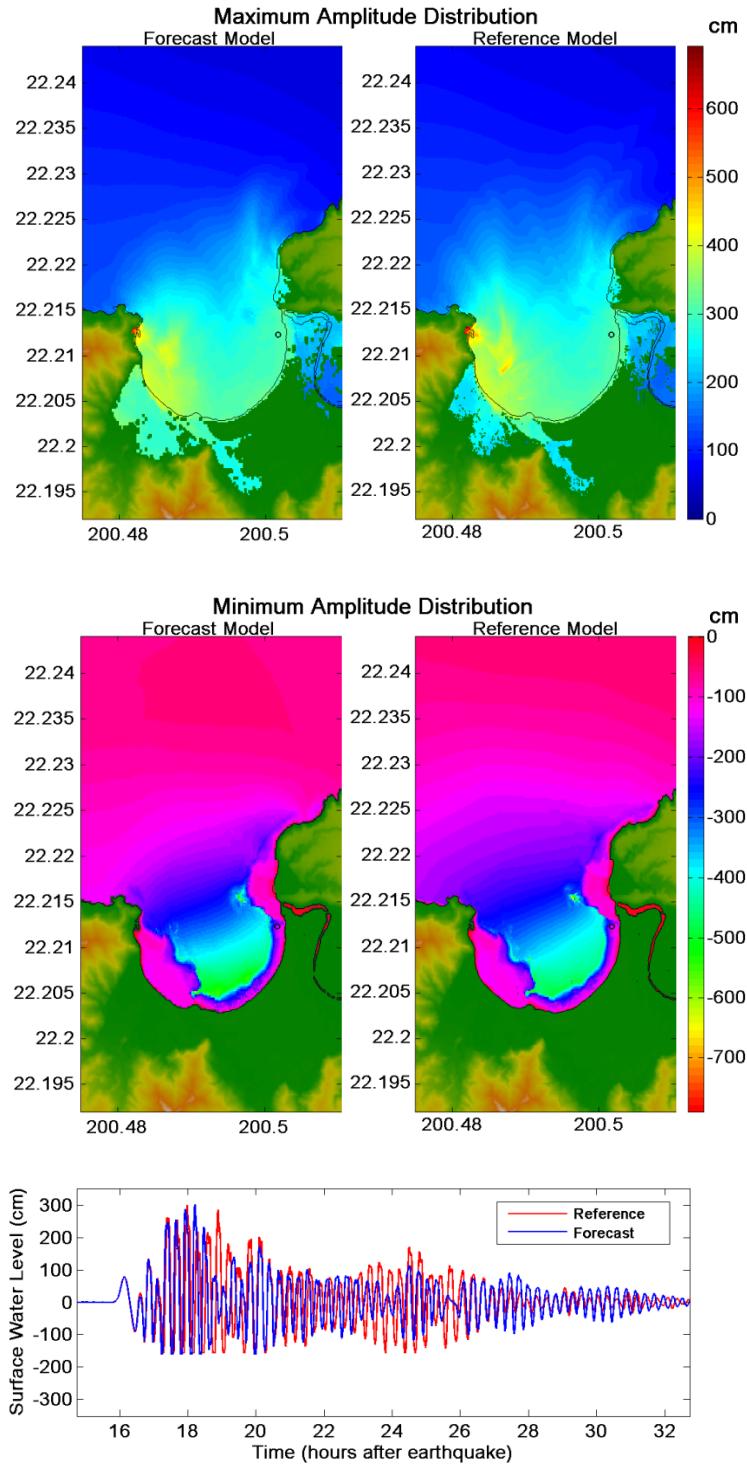


Figure 101. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS101-110; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

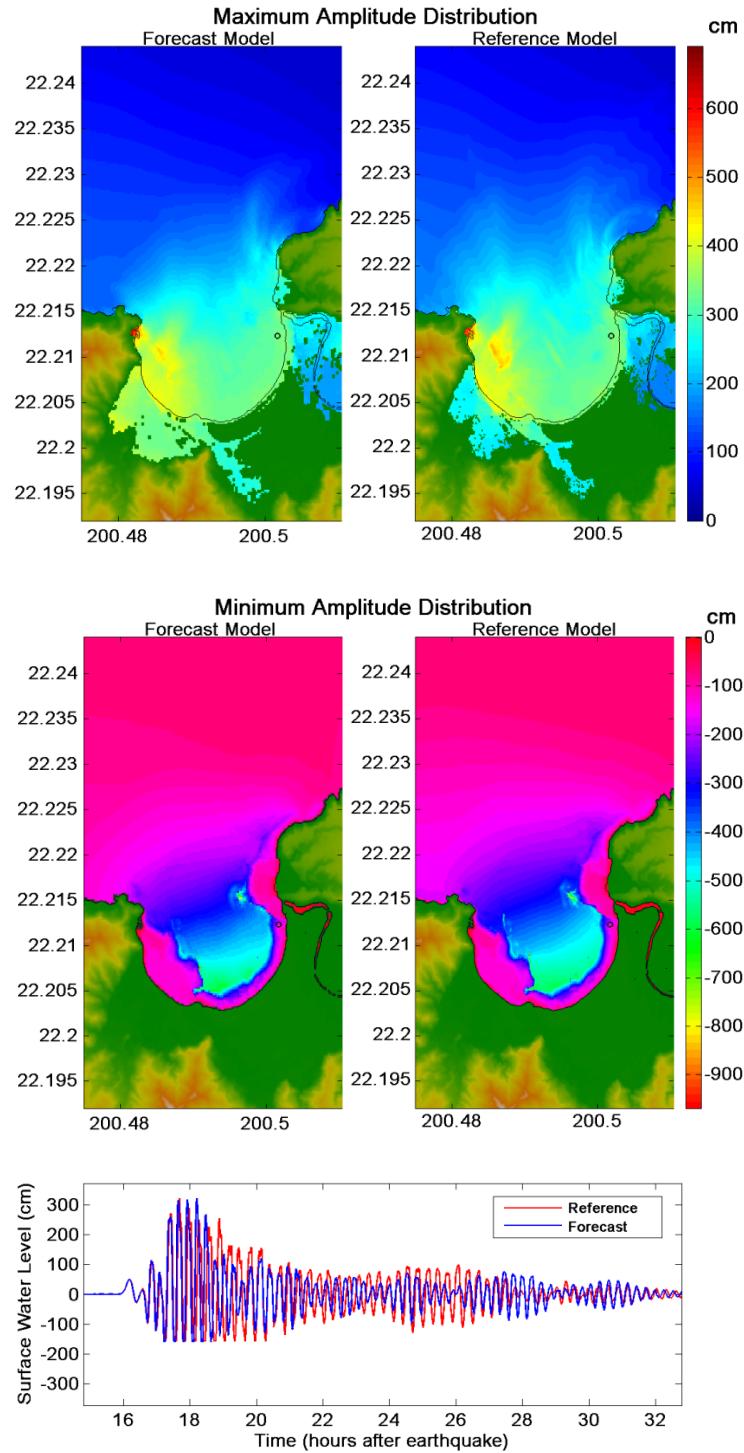


Figure 102. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event CS106-115; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

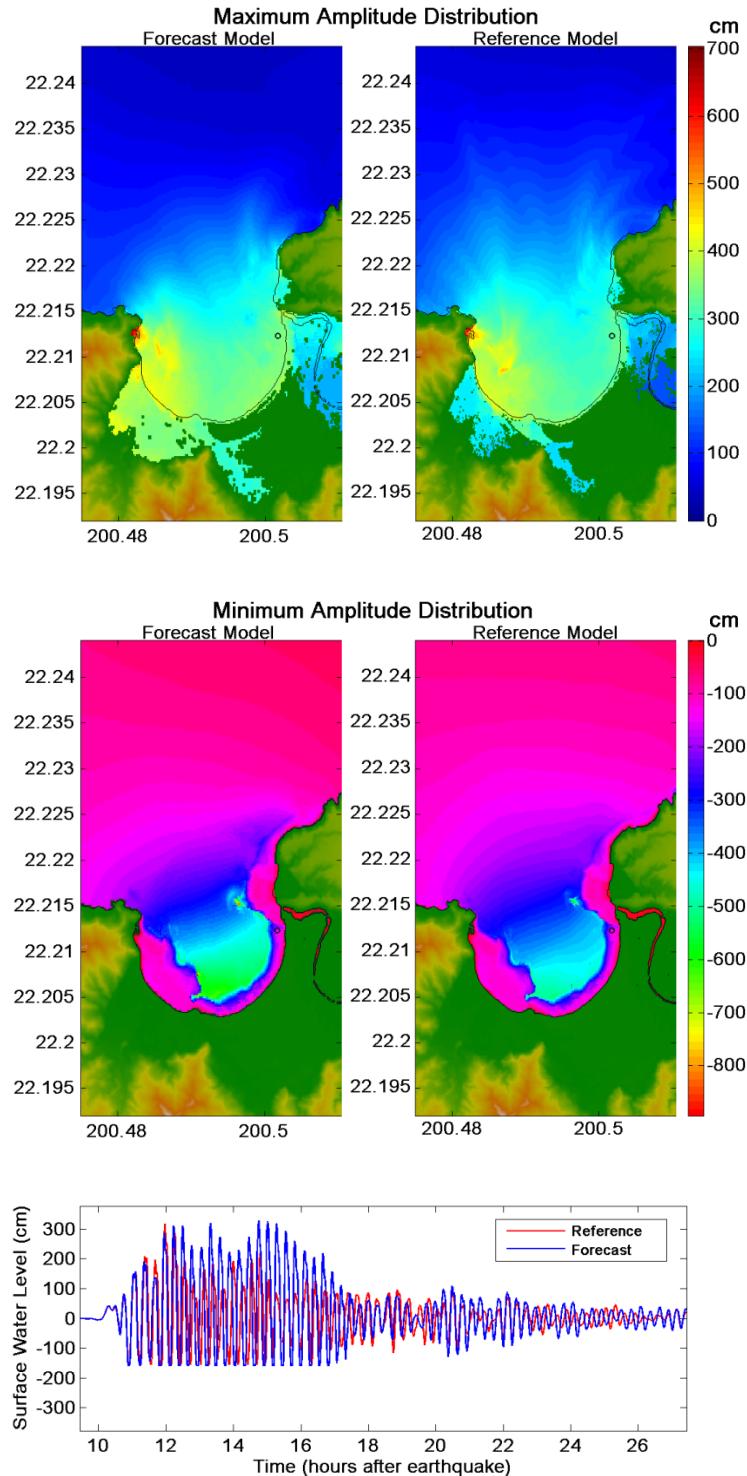


Figure 103. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event EP01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

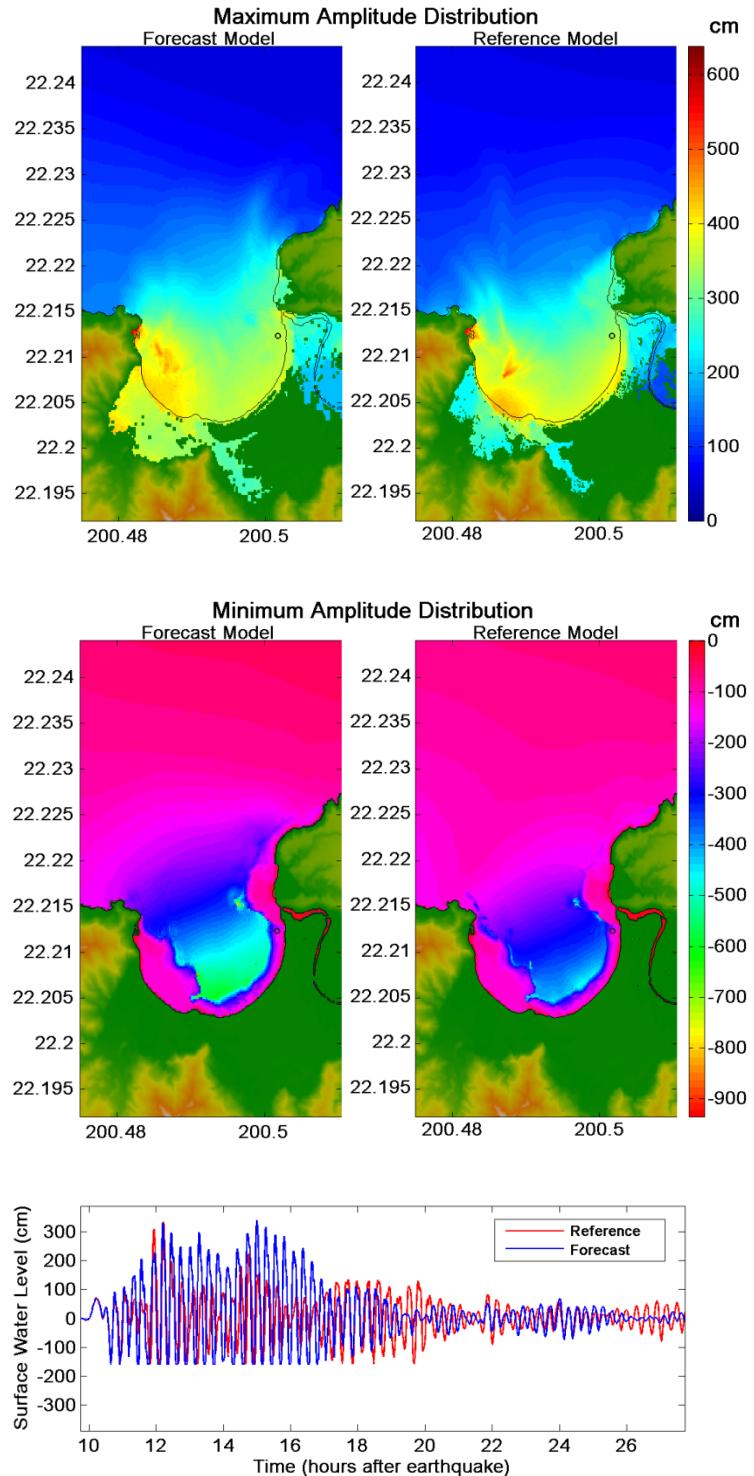


Figure 104. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event EP06-15; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

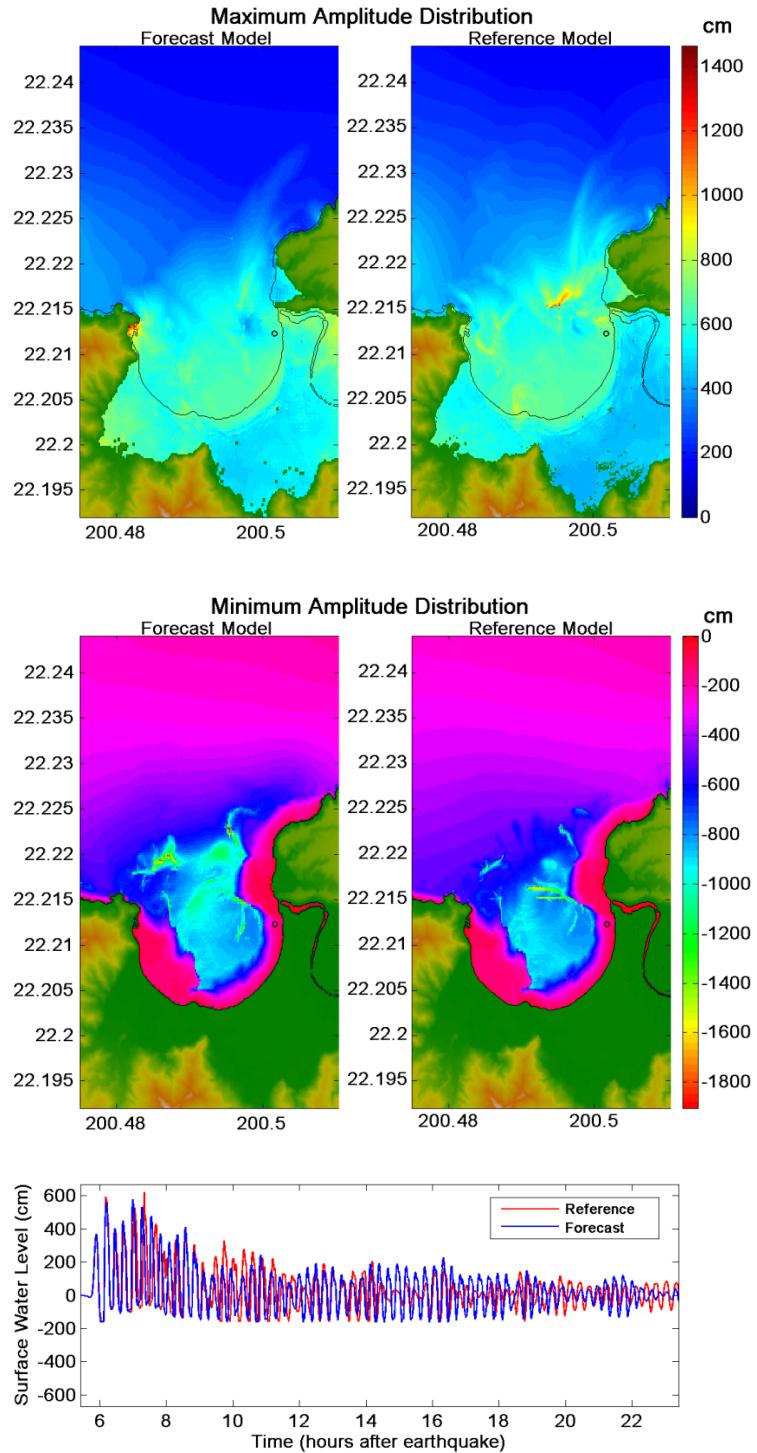


Figure 105. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

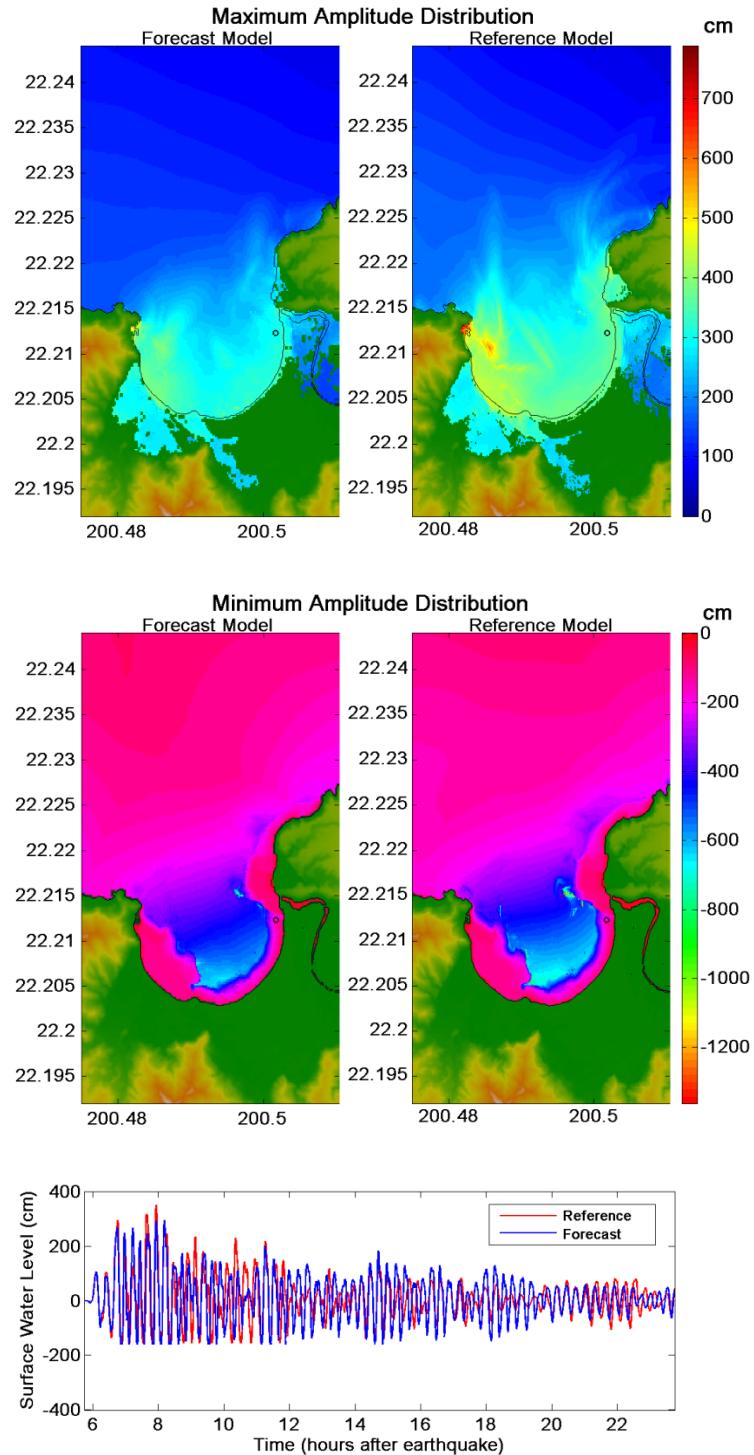


Figure 106. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI11-20; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

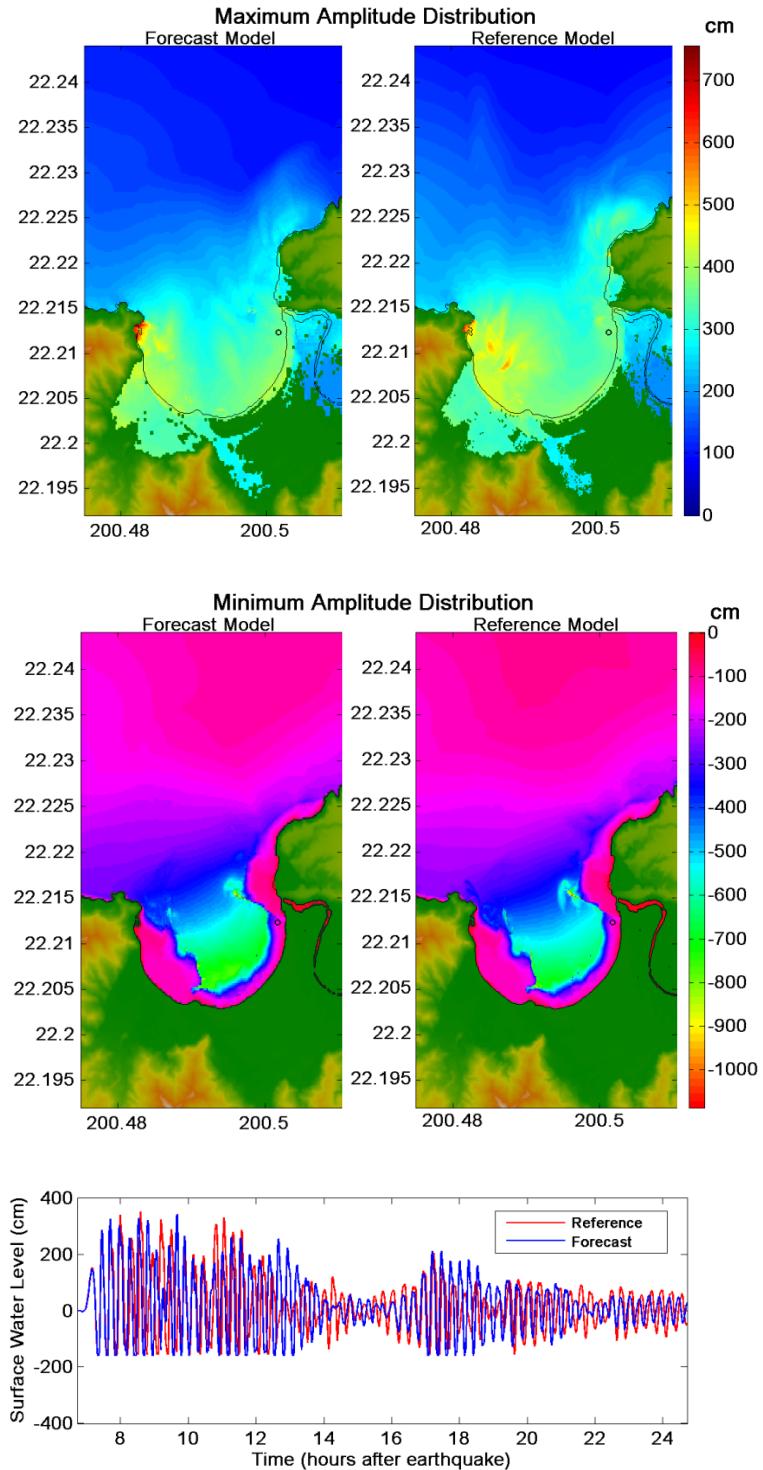


Figure 107. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI22-31; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

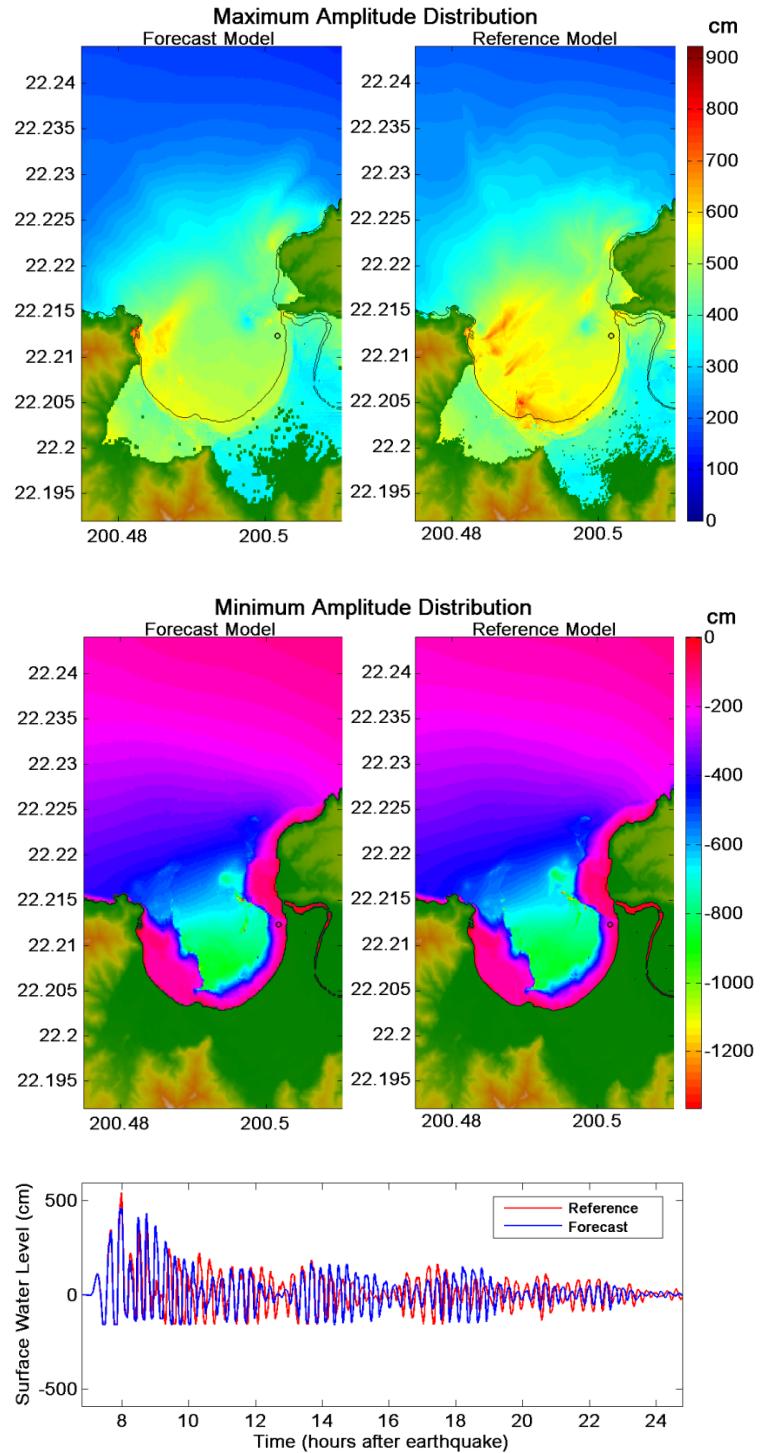


Figure 108. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI32-41; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

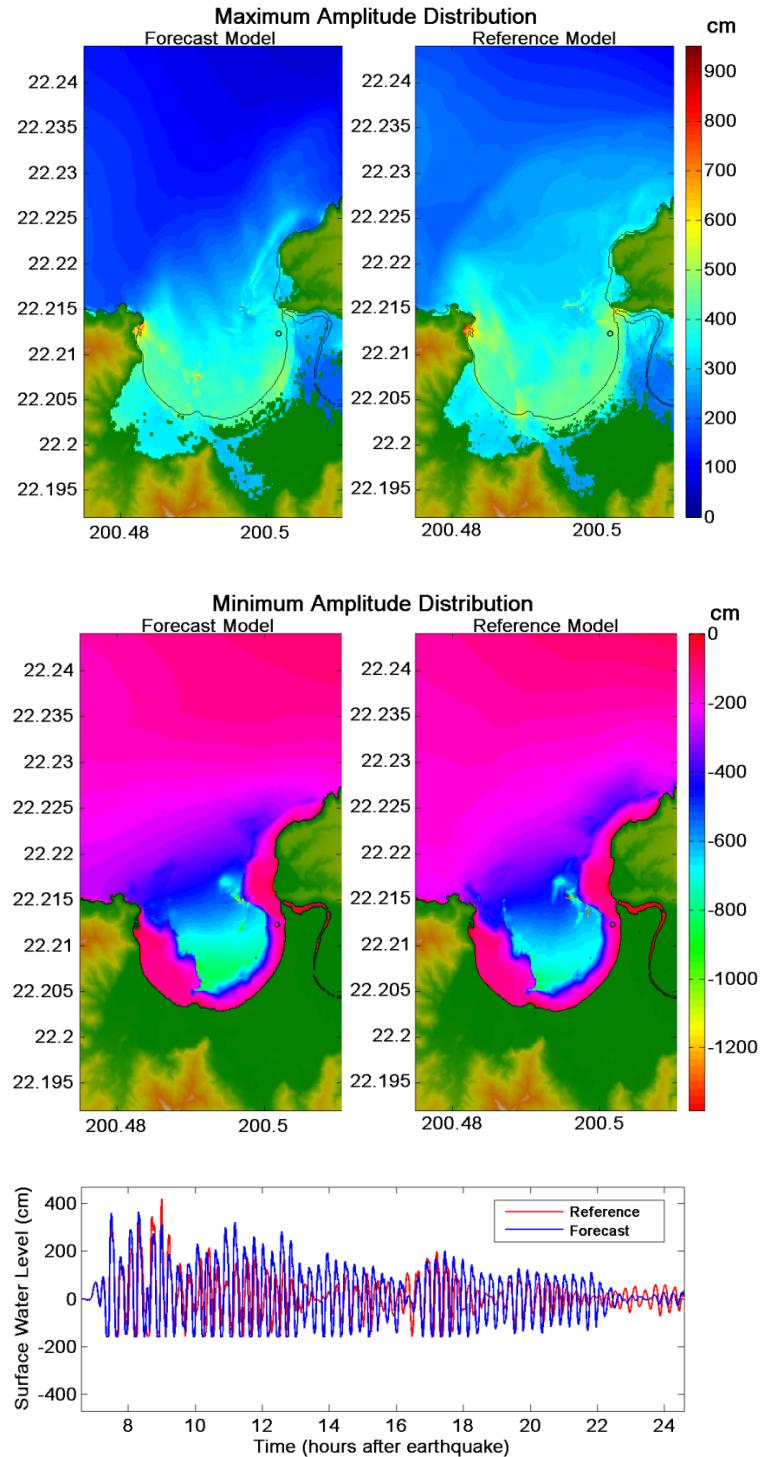


Figure 109. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI42-51; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

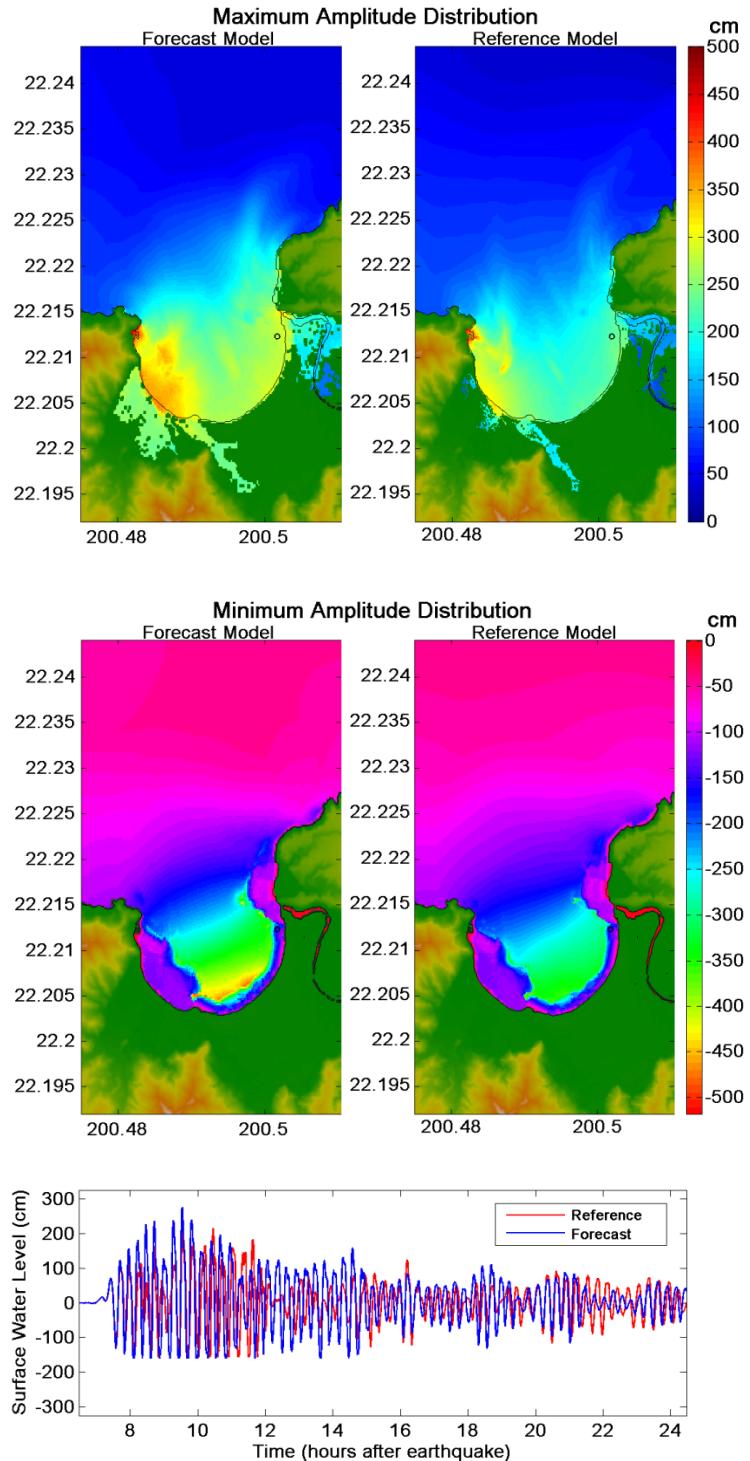


Figure 110. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI52-61; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

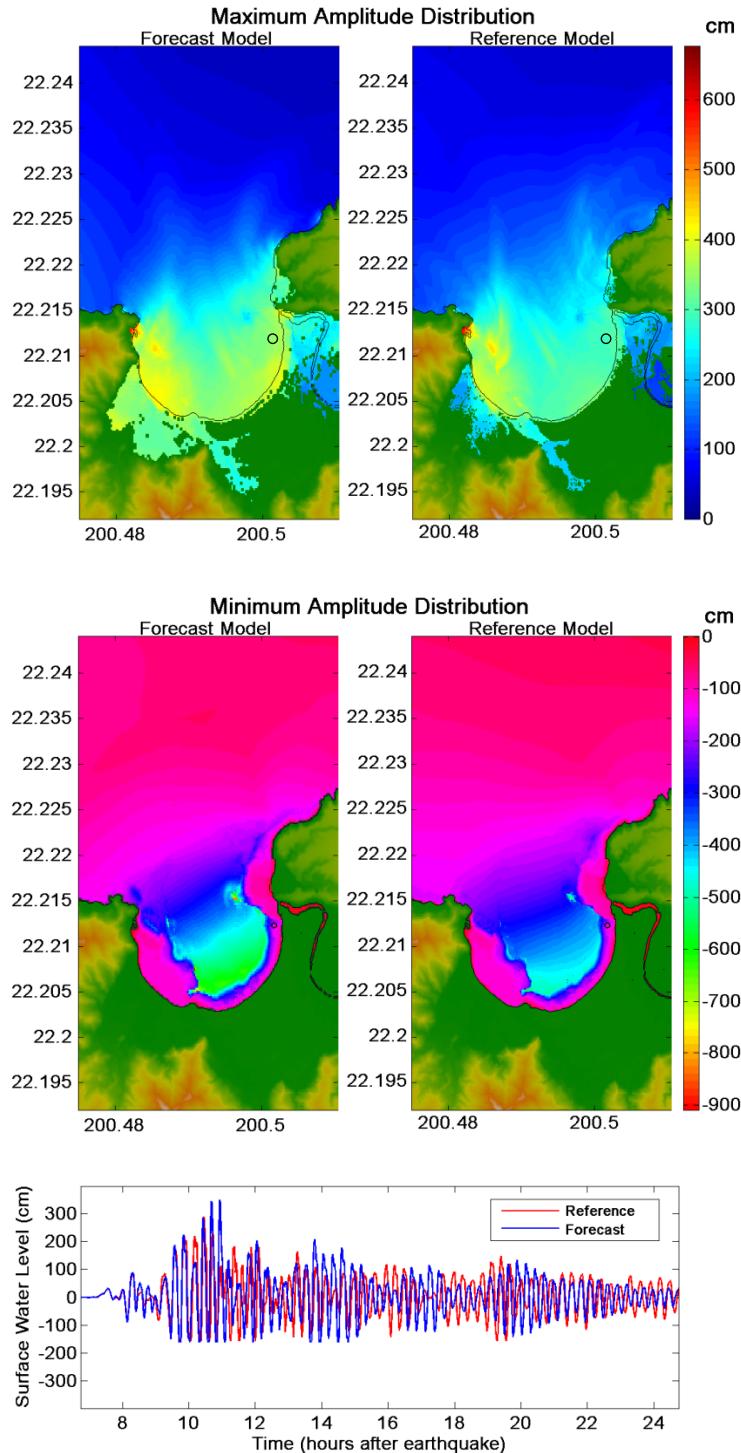


Figure 111. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI56-65; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

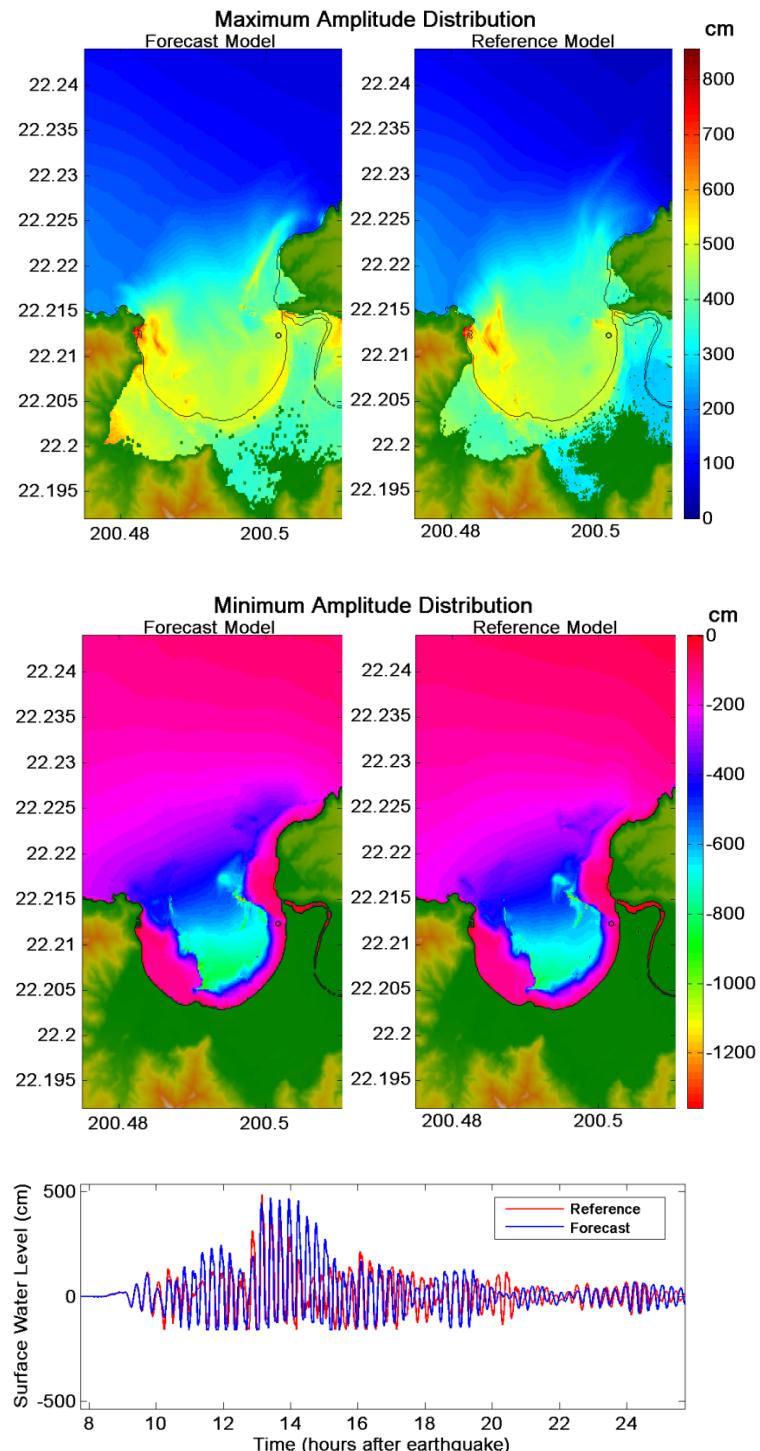


Figure 112. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event KI66-75; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

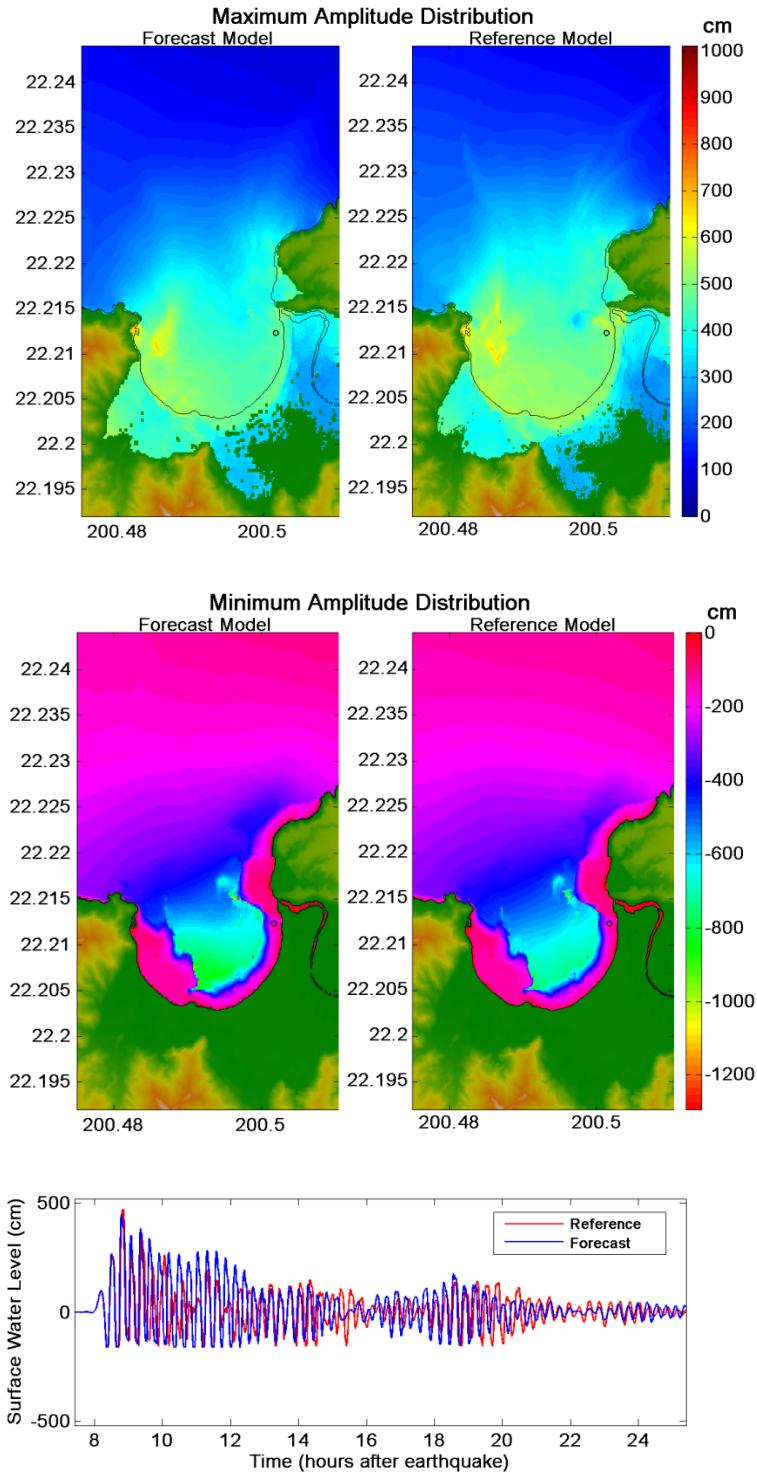


Figure 113. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event MO01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

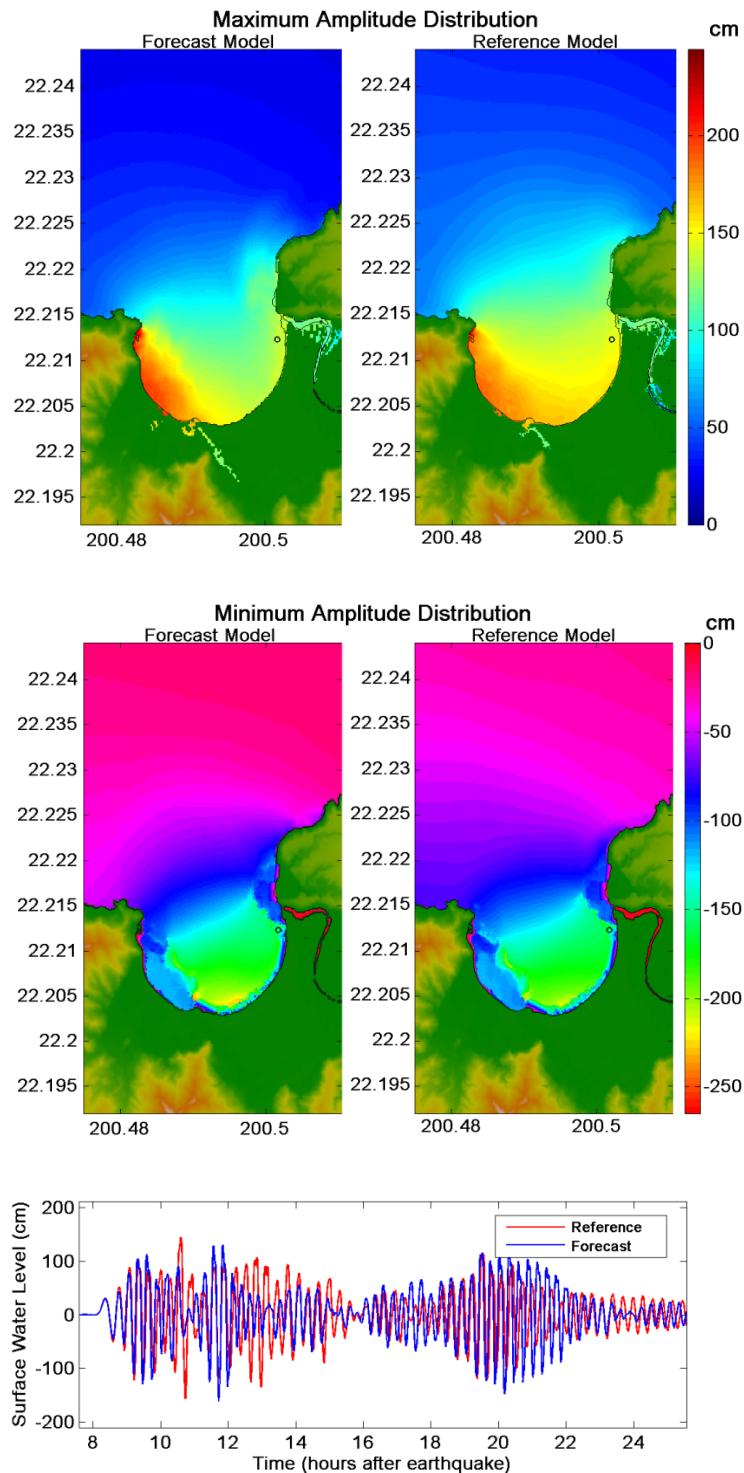


Figure 114. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event MO06-15; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

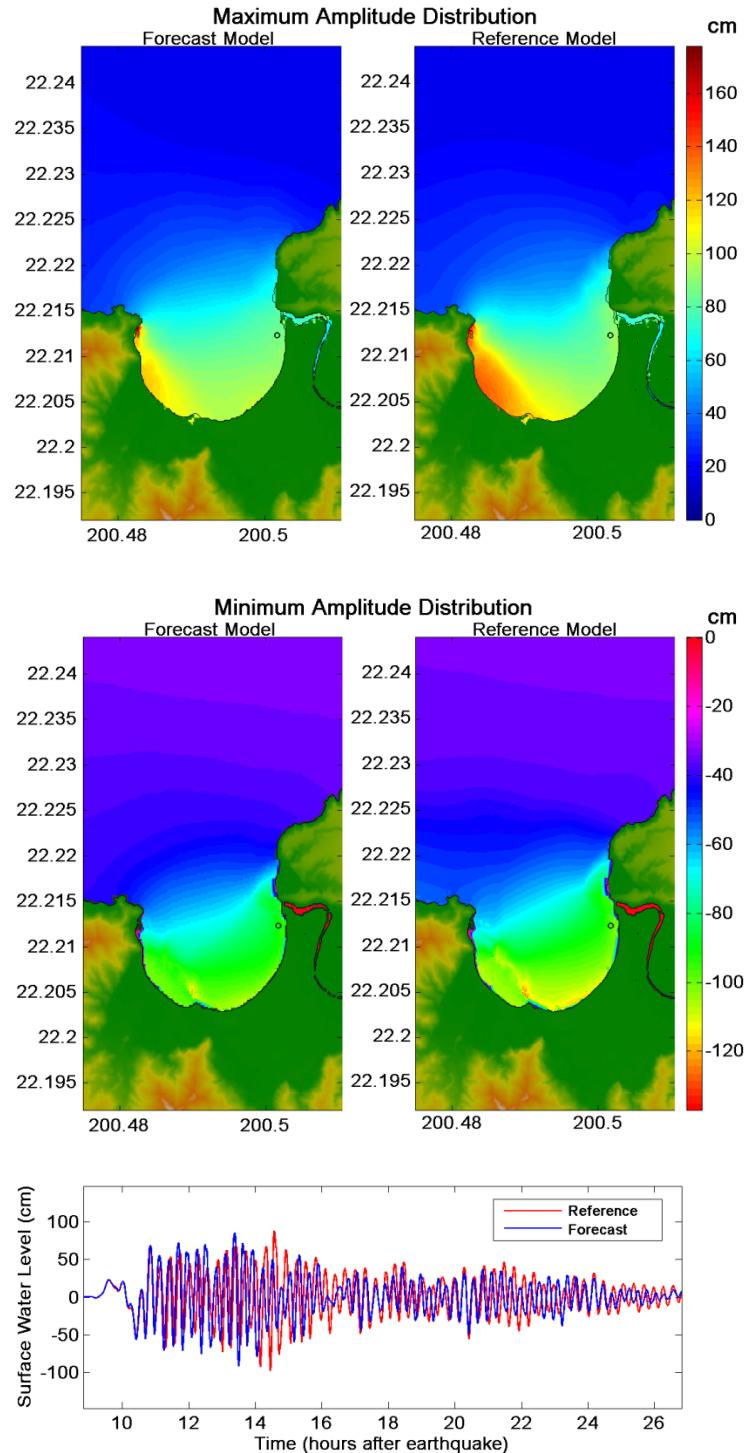


Figure 115. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NG01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

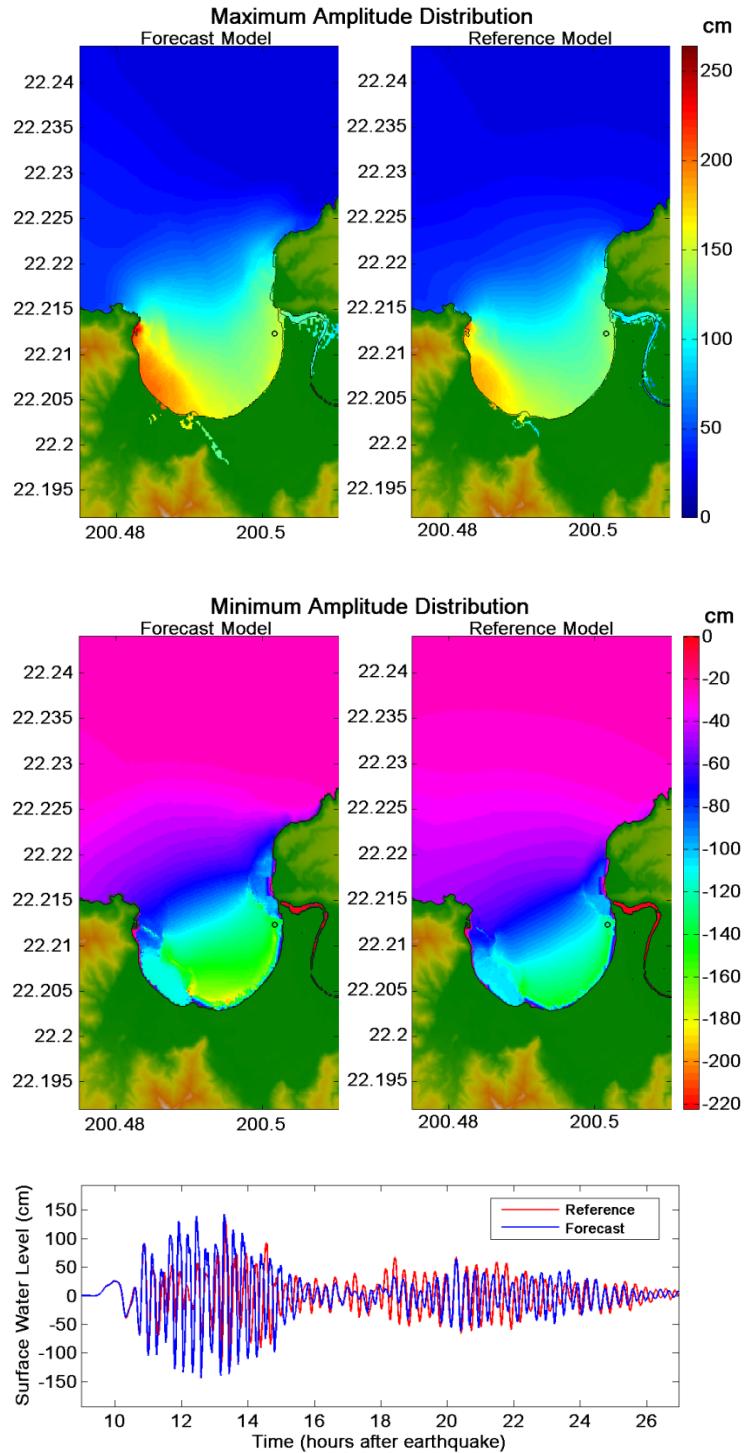


Figure 116. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NG06-15; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

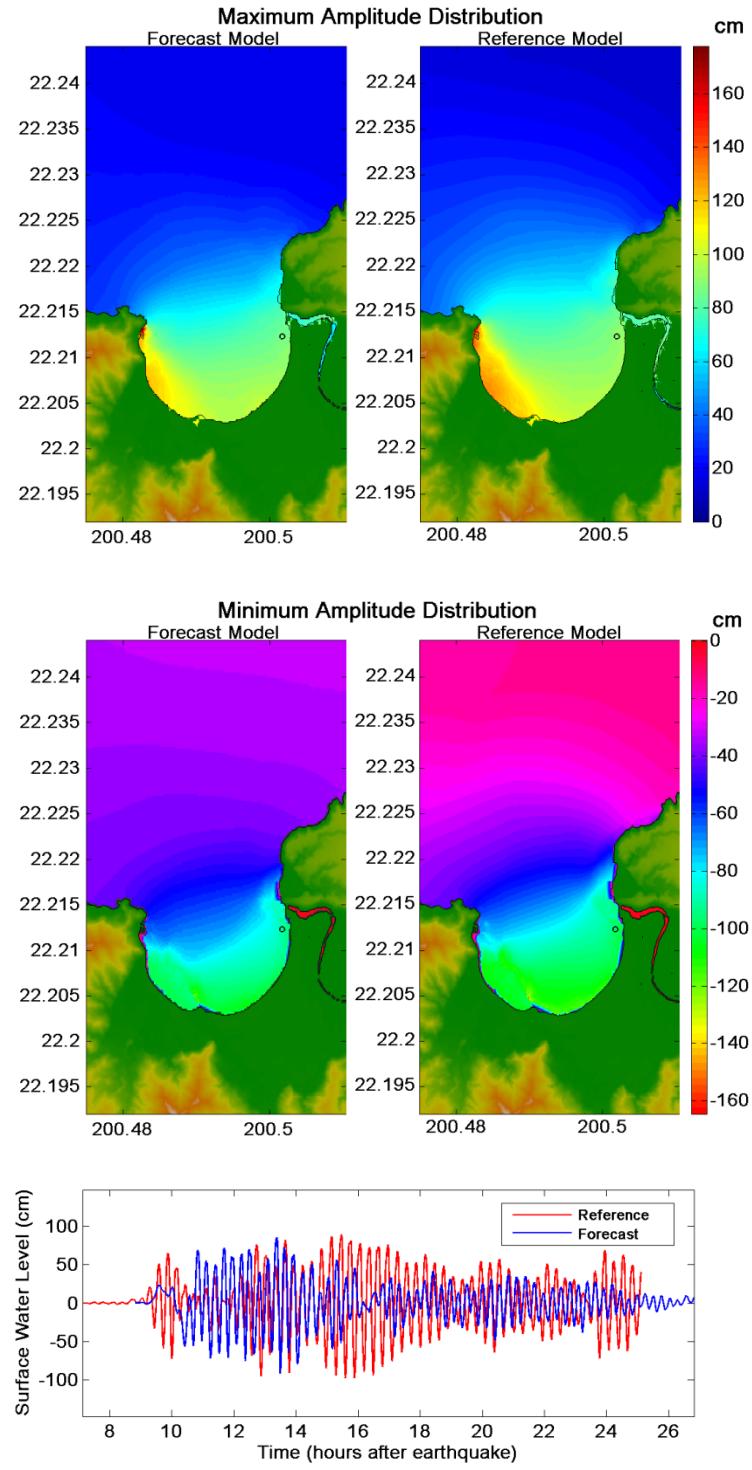


Figure 117. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NT01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

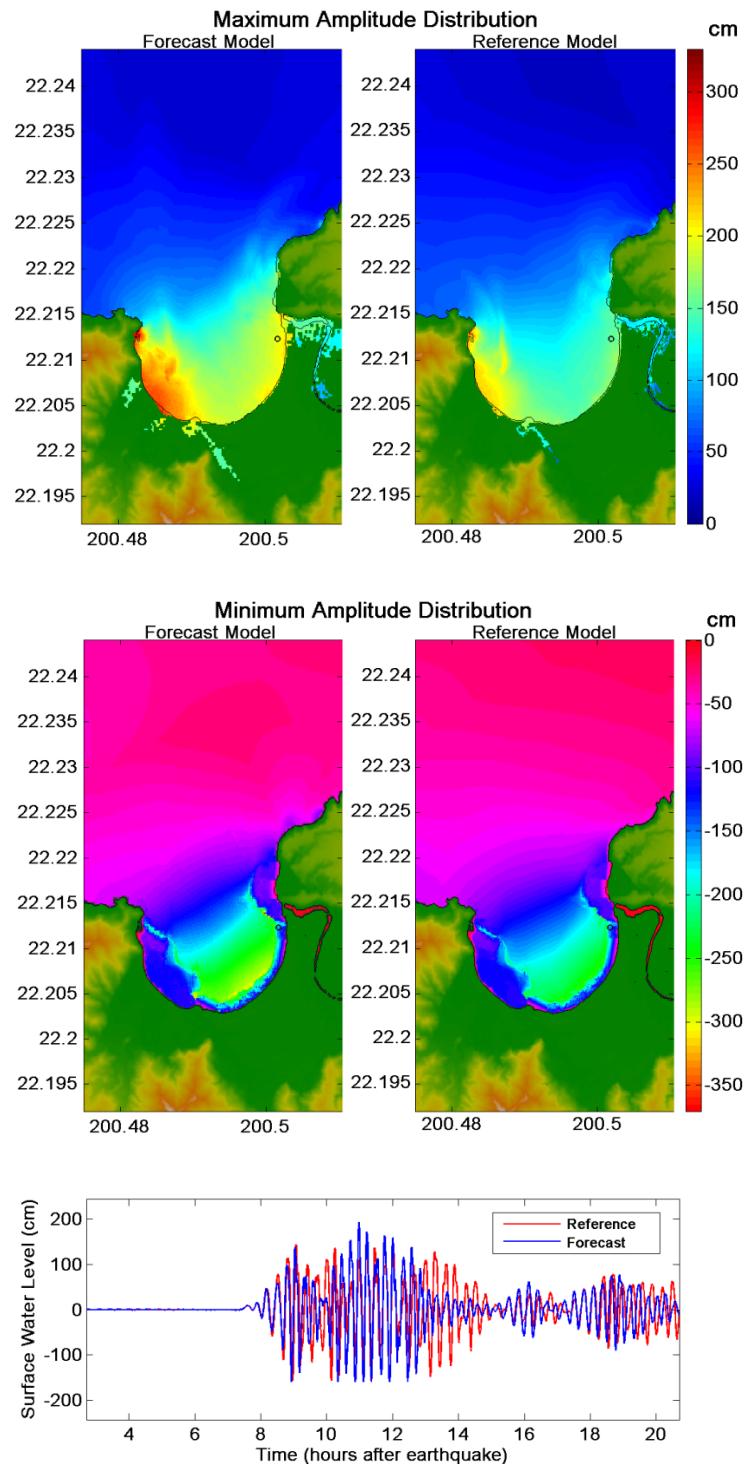


Figure 118. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NT11-20; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

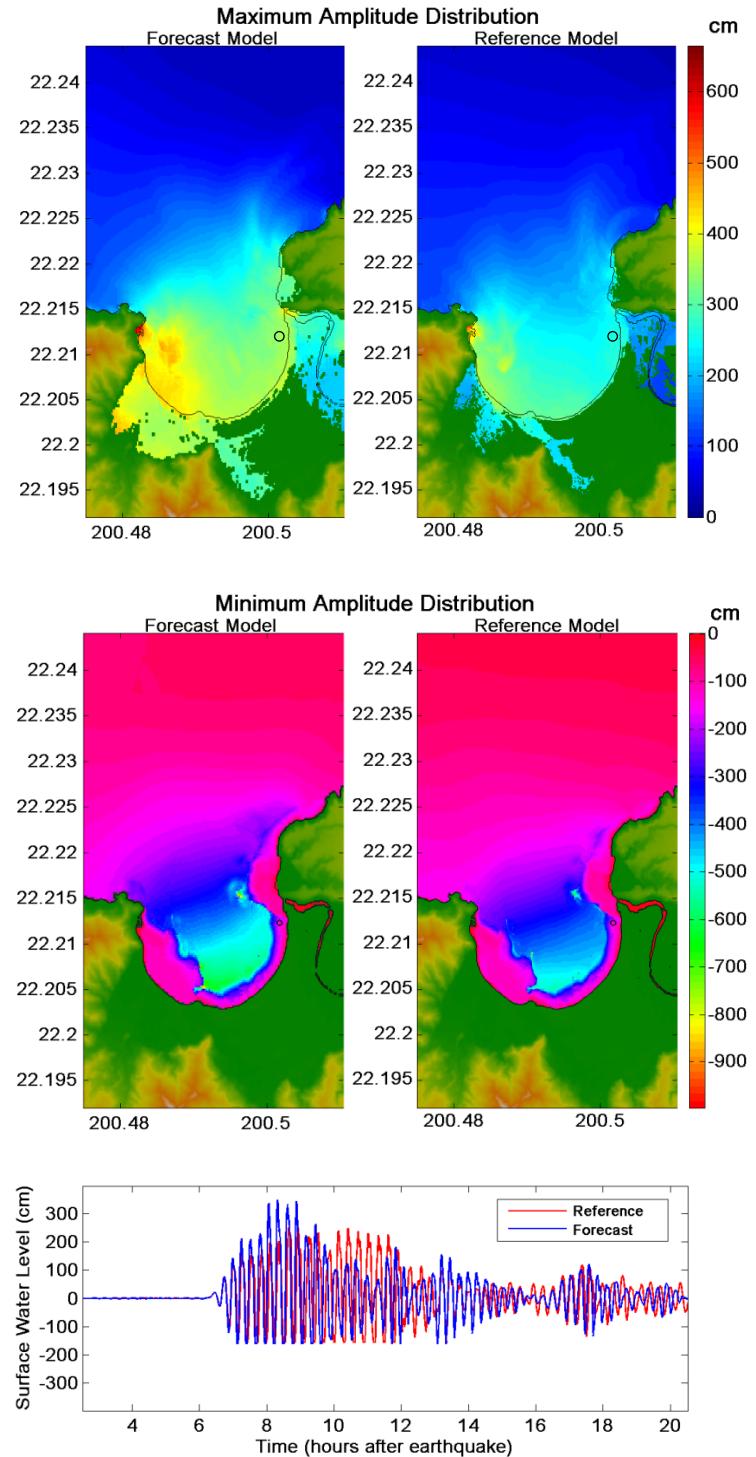


Figure 119. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NT21-30; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

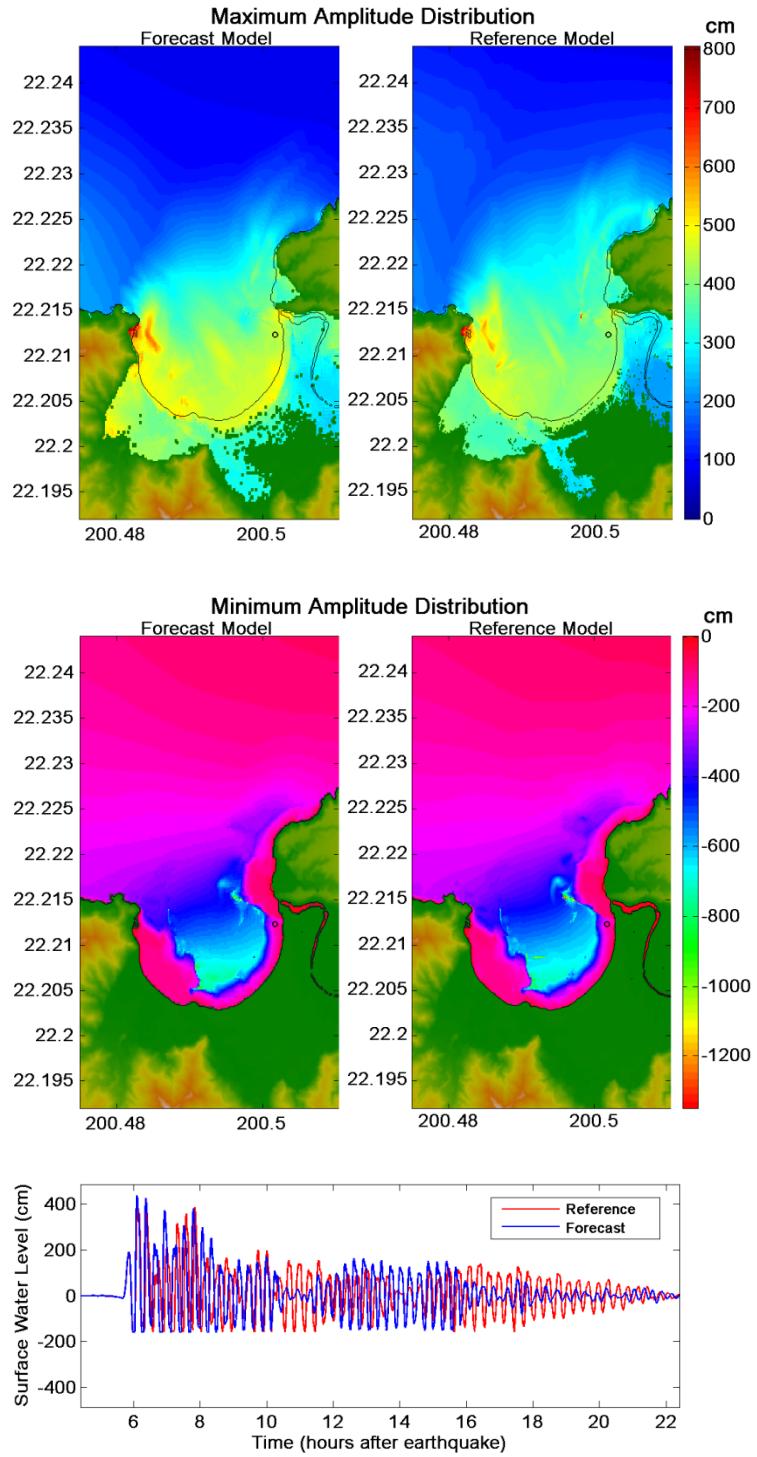


Figure 120. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NT30-39; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

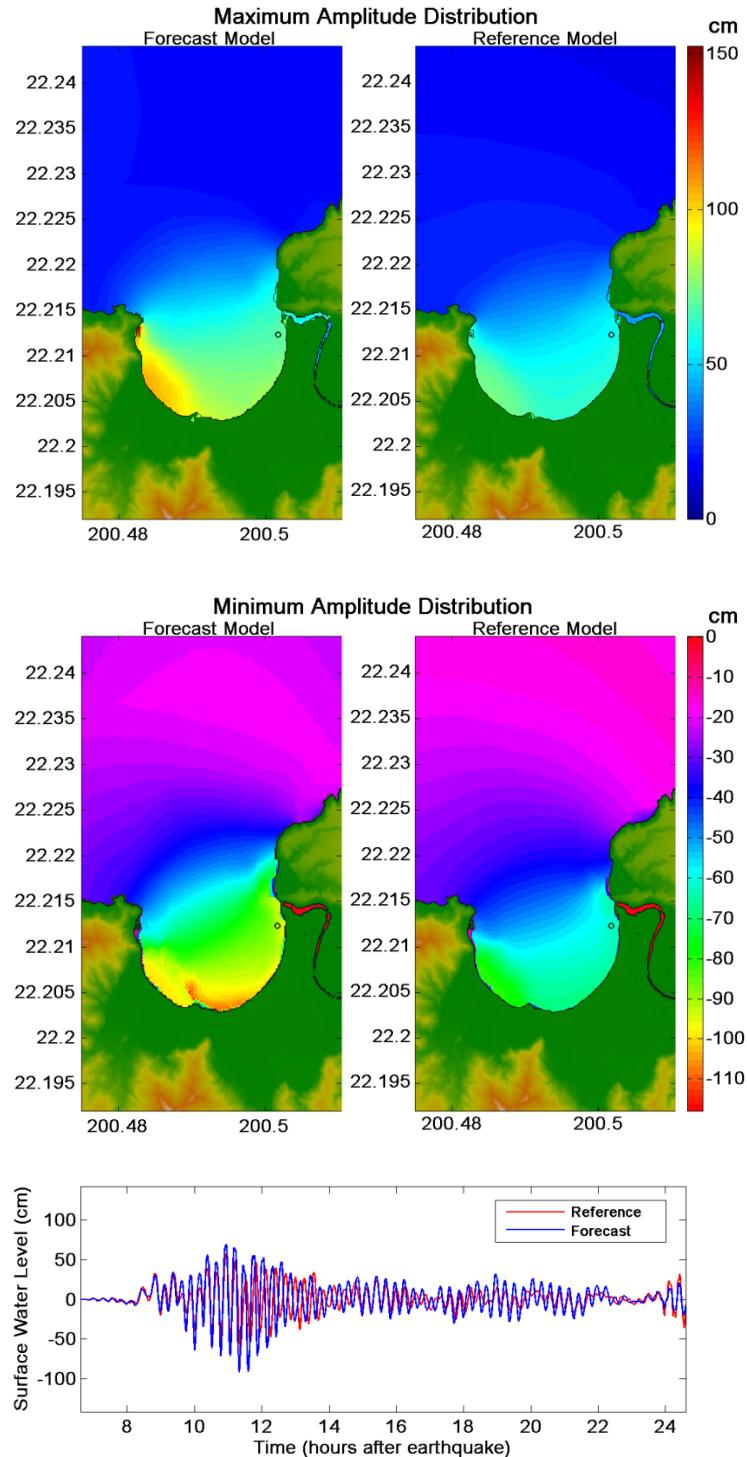


Figure 121. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NV01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

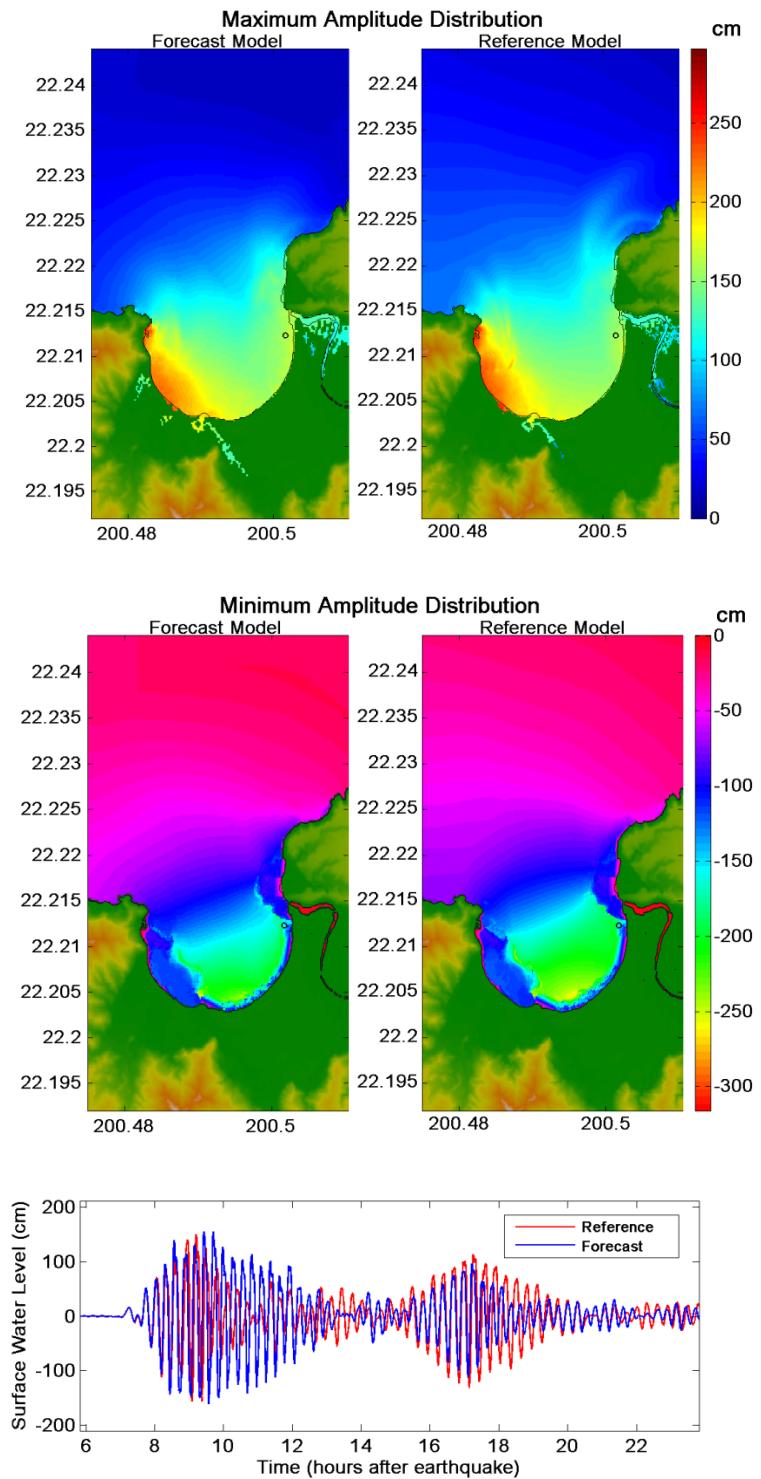


Figure 122. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NV11-20; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

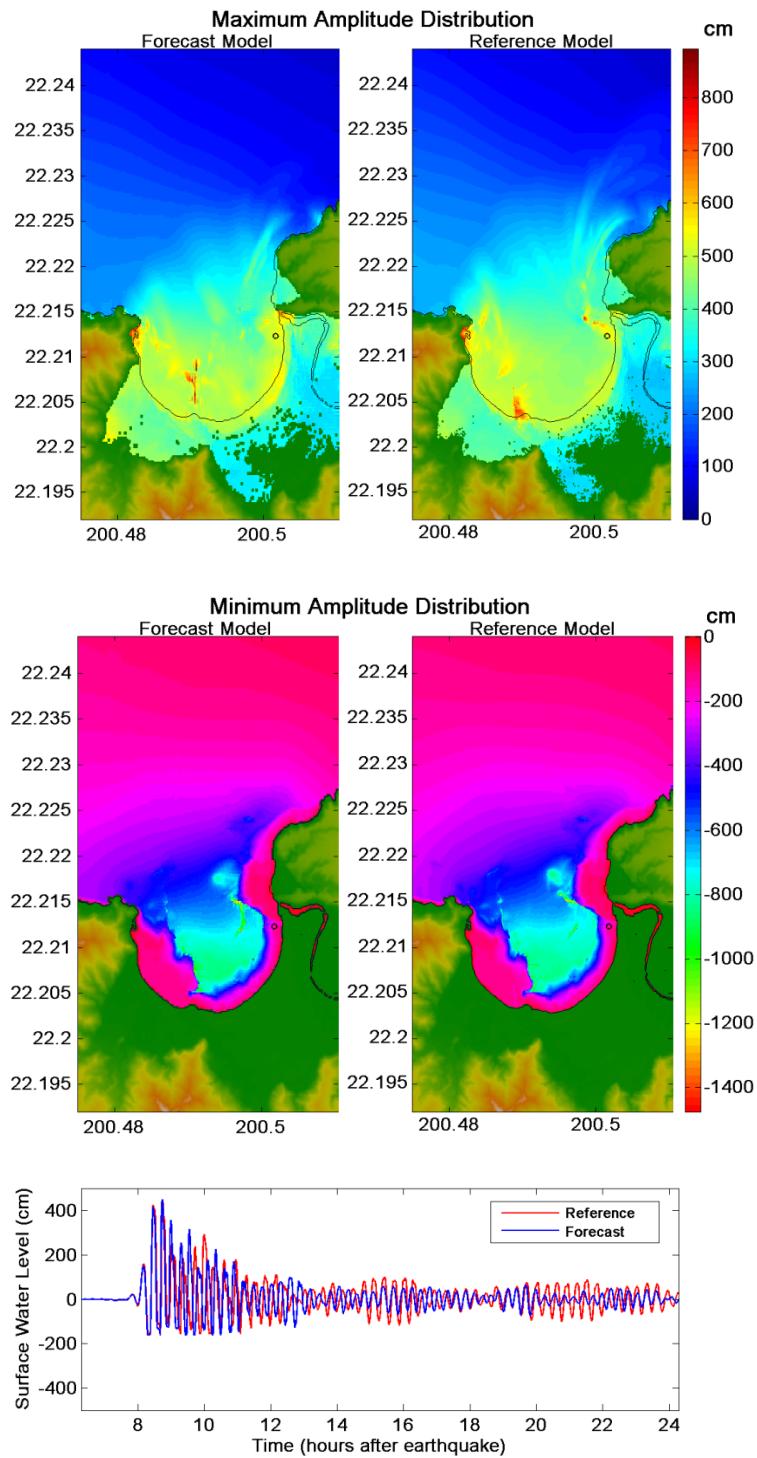


Figure 123. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event NV28-37; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

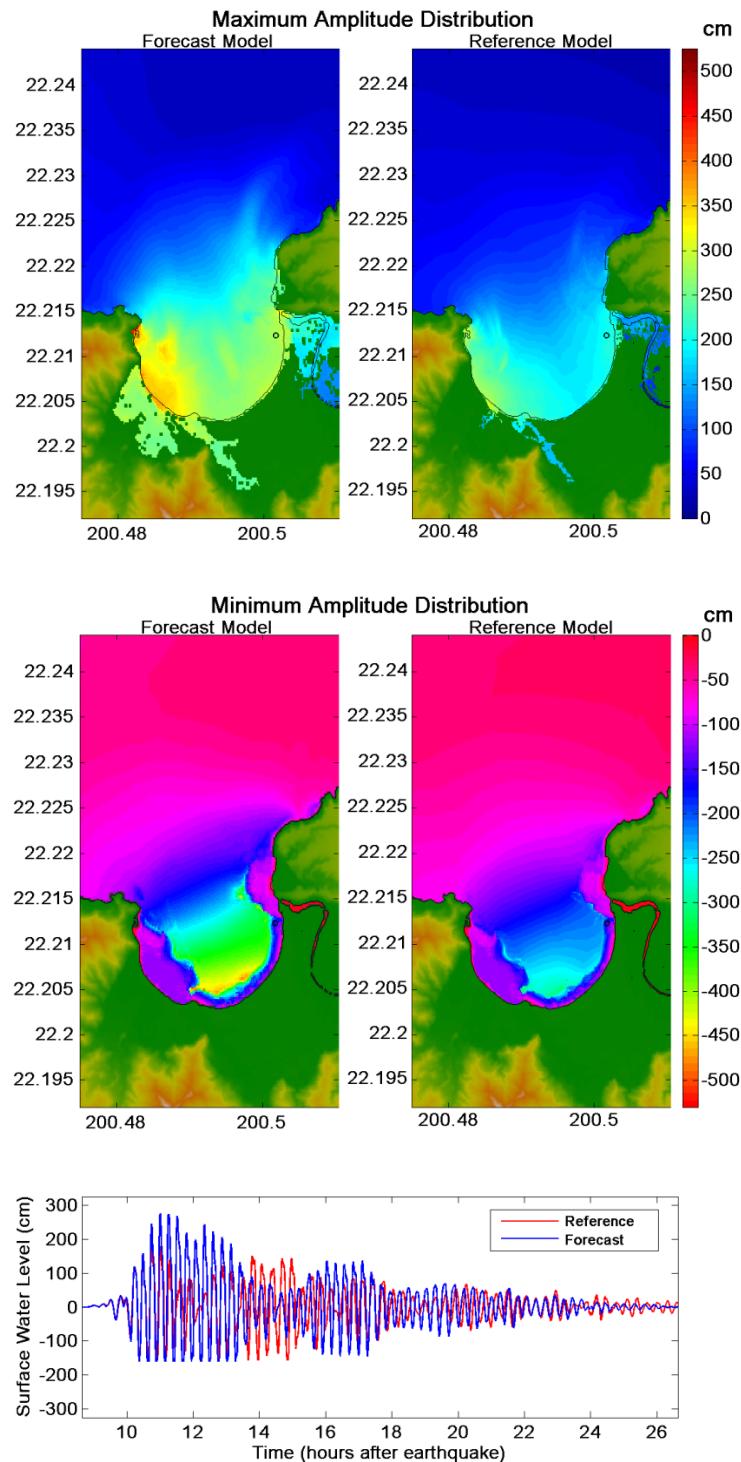


Figure 124. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event RN01-10; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

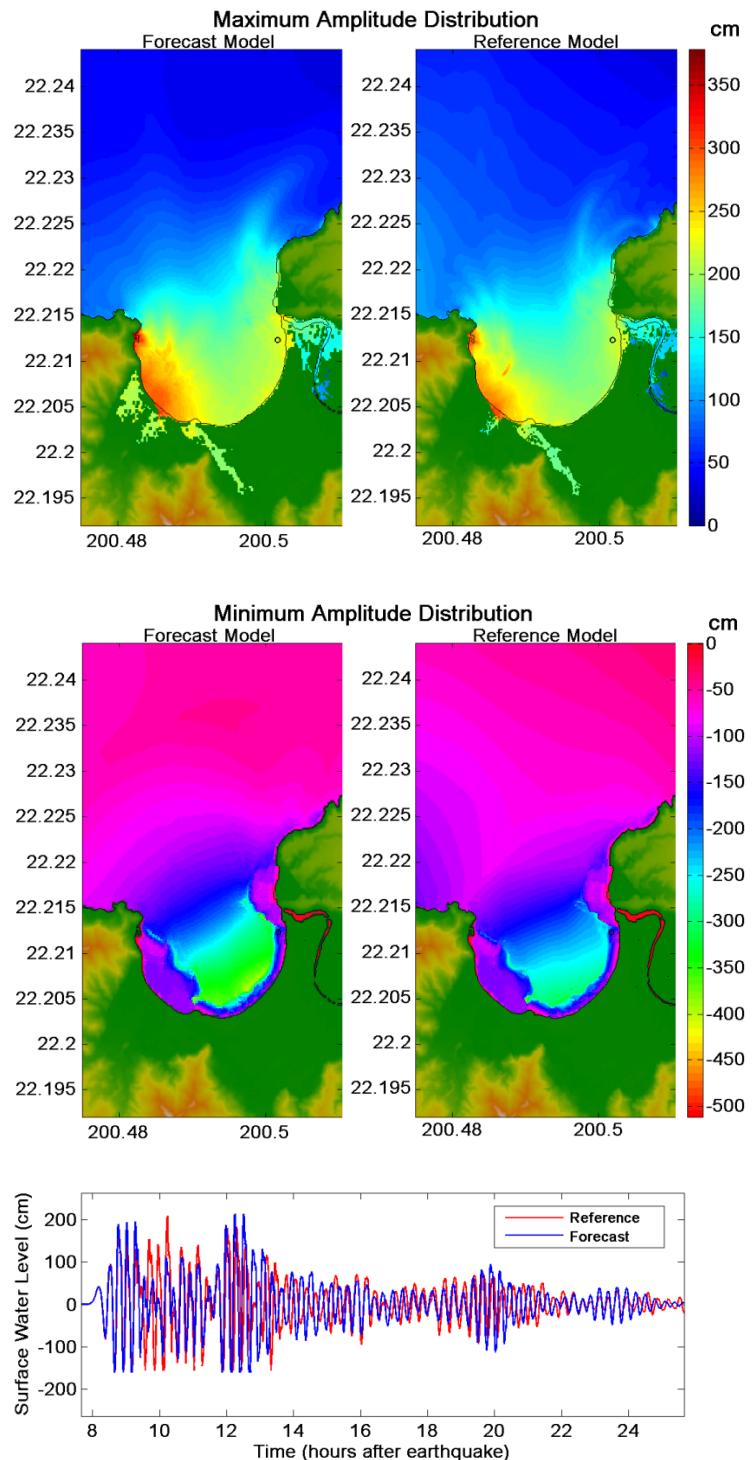


Figure 125. Tsunami wave amplitude distribution at C-grid level of synthetic mega-event RN13-22; maximum wave amplitude (upper figures), minimum wave amplitude distribution (middle figures); tsunami time series at warning point (lower figure). Circle is the selected warning point location.

## **Appendix A**

Development of the Hanalei, Hawai‘i tsunami forecast model occurred prior to parameter changes that were made to reflect modifications to the MOST model code. As a result, the input file for running both the optimized tsunami forecast model and the high-resolution reference inundation model in MOST have been updated accordingly. Appendix A1 and A2 provide the updated files for Hanalei, Hawai‘i.

### **A1. Reference model \*.in file for Hanalei, Hawai‘i**

0.0001	Minimum amplitude of input offshore wave (m)
1	Input minimum depth for offshore (m)
0.1	Input "dry land" depth for inundation (m)
0.0009	Input friction coefficient ( $n^{**2}$ )
1	A & B-grid runup flag (0=disallow, 1=allow runup)
300.0	Blow-up limit (maximum eta before blow-up)
0.3	Input time step (sec)
288000	Input number of steps
10	Compute "A" arrays every $n^{\text{th}}$ time step, n=
1	Compute "B" arrays every $n^{\text{th}}$ time step, n=
60	Input number of steps between snapshots
1	...Starting from
1	...Saving grid every $n^{\text{th}}$ node, n=1

### **A2. Forecast model \*.in file for Hanalei, Hawai‘i**

0.0001	Minimum amplitude of input offshore wave (m)
1	Input minimum depth for offshore (m)
0.1	Input "dry land" depth for inundation (m)
0.0009	Input friction coefficient ( $n^{**2}$ )
1	A & B-grid runup flag (0=disallow, 1=allow runup)
300	Blow-up limit (maximum eta before blow-up)
1	Input time step (sec)
86400	Input number of steps
6	Compute "A" arrays every $n^{\text{th}}$ time step, n=
2	Compute "B" arrays every $n^{\text{th}}$ time step, n=
60	Input number of steps between snapshots
1	...Starting from
1	...Saving grid every $n^{\text{th}}$ node, n=1

## Appendix B.

Propagation source details reflect the database as of January 29, 2013. The development of Hanalei, Hawai‘i forecast inundation model uses the propagation database as of 2011 thus there is a possibility of changes due to updates in the earthquake source parameters after this date.

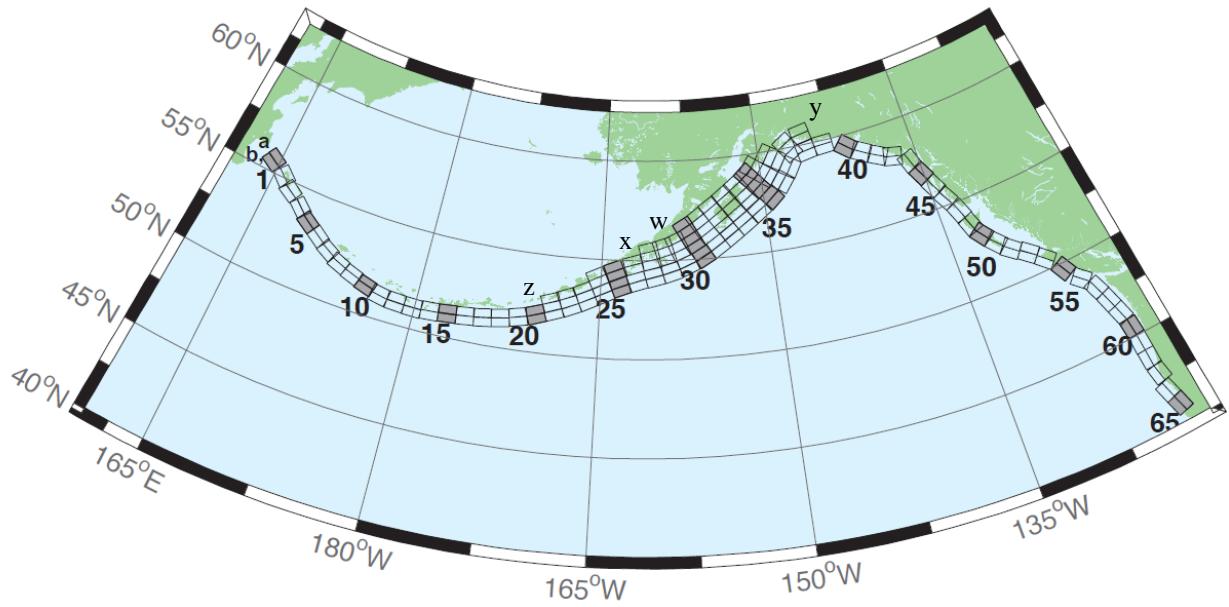


Figure 126. Aleutian-Alaska-Cascadia Subduction Zone unit sources

Table 7. Earthquake parameters for Aleutian-Alaska-Cascadia Subduction Zone unit sources.

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
acsz-01a	Aleutian-Alaska-Cascadia	164.7994	55.9606	17.00	299.00	19.61
acsz-01b	Aleutian-Alaska-Cascadia	164.4310	55.5849	17.00	299.00	5.00
acsz-02a	Aleutian-Alaska-Cascadia	166.3418	55.4016	17.00	310.17	19.61
acsz-02b	Aleutian-Alaska-Cascadia	165.8578	55.0734	17.00	310.17	5.00
acsz-03a	Aleutian-Alaska-Cascadia	167.2939	54.8919	23.36	300.22	24.82
acsz-03b	Aleutian-Alaska-Cascadia	166.9362	54.5356	23.36	300.22	5.00
acsz-04a	Aleutian-Alaska-Cascadia	168.7131	54.2852	38.51	310.21	25.33
acsz-04b	Aleutian-Alaska-Cascadia	168.3269	54.0168	24.00	310.21	5.00
acsz-05a	Aleutian-Alaska-Cascadia	169.7447	53.7808	37.02	302.77	23.54
acsz-05b	Aleutian-Alaska-Cascadia	169.4185	53.4793	21.77	302.77	5.00
acsz-06a	Aleutian-Alaska-Cascadia	171.0144	53.3054	35.31	303.16	22.92
acsz-06b	Aleutian-Alaska-Cascadia	170.6813	52.9986	21.00	303.16	5.00
acsz-07a	Aleutian-Alaska-Cascadia	172.1500	52.8528	35.56	298.16	20.16
acsz-07b	Aleutian-Alaska-Cascadia	171.8665	52.5307	17.65	298.16	5.00
acsz-08a	Aleutian-Alaska-Cascadia	173.2726	52.4579	37.92	290.75	20.35
acsz-08b	Aleutian-Alaska-Cascadia	173.0681	52.1266	17.88	290.75	5.00
acsz-09a	Aleutian-Alaska-Cascadia	174.5866	52.1434	39.09	289.03	21.05
acsz-09b	Aleutian-Alaska-Cascadia	174.4027	51.8138	18.73	289.03	5.00
acsz-10a	Aleutian-Alaska-Cascadia	175.8784	51.8526	40.51	286.07	20.87
acsz-10b	Aleutian-Alaska-Cascadia	175.7265	51.5245	18.51	286.07	5.00
acsz-11a	Aleutian-Alaska-Cascadia	177.1140	51.6488	15.00	280.00	17.94
acsz-11b	Aleutian-Alaska-Cascadia	176.9937	51.2215	15.00	280.00	5.00
acsz-12a	Aleutian-Alaska-Cascadia	178.4500	51.5690	15.00	273.00	17.94
acsz-12b	Aleutian-Alaska-Cascadia	178.4130	51.1200	15.00	273.00	5.00
acsz-13a	Aleutian-Alaska-Cascadia	179.8550	51.5340	15.00	271.00	17.94
acsz-13b	Aleutian-Alaska-Cascadia	179.8420	51.0850	15.00	271.00	5.00
acsz-14a	Aleutian-Alaska-Cascadia	181.2340	51.5780	15.00	267.00	17.94
acsz-14b	Aleutian-Alaska-Cascadia	181.2720	51.1290	15.00	267.00	5.00
acsz-15a	Aleutian-Alaska-Cascadia	182.6380	51.6470	15.00	265.00	17.94
acsz-15b	Aleutian-Alaska-Cascadia	182.7000	51.2000	15.00	265.00	5.00
acsz-16a	Aleutian-Alaska-Cascadia	184.0550	51.7250	15.00	264.00	17.94
acsz-16b	Aleutian-Alaska-Cascadia	184.1280	51.2780	15.00	264.00	5.00
acsz-17a	Aleutian-Alaska-Cascadia	185.4560	51.8170	15.00	262.00	17.94
acsz-17b	Aleutian-Alaska-Cascadia	185.5560	51.3720	15.00	262.00	5.00

Table 7. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
acsz-18a	Aleutian-Alaska-Cascadia	186.8680	51.9410	15.00	261.00	17.94
acsz-18b	Aleutian-Alaska-Cascadia	186.9810	51.4970	15.00	261.00	5.00
acsz-19a	Aleutian-Alaska-Cascadia	188.2430	52.1280	15.00	257.00	17.94
acsz-19b	Aleutian-Alaska-Cascadia	188.4060	51.6900	15.00	257.00	5.00
acsz-20a	Aleutian-Alaska-Cascadia	189.5810	52.3550	15.00	251.00	17.94
acsz-20b	Aleutian-Alaska-Cascadia	189.8180	51.9300	15.00	251.00	5.00
acsz-21a	Aleutian-Alaska-Cascadia	190.9570	52.6470	15.00	251.00	17.94
acsz-21b	Aleutian-Alaska-Cascadia	191.1960	52.2220	15.00	251.00	5.00
acsz-21z	Aleutian-Alaska-Cascadia	190.7399	53.0443	15.00	250.79	30.88
acsz-22a	Aleutian-Alaska-Cascadia	192.2940	52.9430	15.00	247.00	17.94
acsz-22b	Aleutian-Alaska-Cascadia	192.5820	52.5300	15.00	247.00	5.00
acsz-22z	Aleutian-Alaska-Cascadia	192.0074	53.3347	15.00	247.82	30.88
acsz-23a	Aleutian-Alaska-Cascadia	193.6270	53.3070	15.00	245.00	17.94
acsz-23b	Aleutian-Alaska-Cascadia	193.9410	52.9000	15.00	245.00	5.00
acsz-23z	Aleutian-Alaska-Cascadia	193.2991	53.6768	15.00	244.58	30.88
acsz-24a	Aleutian-Alaska-Cascadia	194.9740	53.6870	15.00	245.00	17.94
acsz-24b	Aleutian-Alaska-Cascadia	195.2910	53.2800	15.00	245.00	5.00
acsz-24y	Aleutian-Alaska-Cascadia	194.3645	54.4604	15.00	244.38	43.82
acsz-24z	Aleutian-Alaska-Cascadia	194.6793	54.0674	15.00	244.64	30.88
acsz-25a	Aleutian-Alaska-Cascadia	196.4340	54.0760	15.00	250.00	17.94
acsz-25b	Aleutian-Alaska-Cascadia	196.6930	53.6543	15.00	250.00	5.00
acsz-25y	Aleutian-Alaska-Cascadia	195.9009	54.8572	15.00	247.90	43.82
acsz-25z	Aleutian-Alaska-Cascadia	196.1761	54.4536	15.00	248.12	30.88
acsz-26a	Aleutian-Alaska-Cascadia	197.8970	54.3600	15.00	253.00	17.94
acsz-26b	Aleutian-Alaska-Cascadia	198.1200	53.9300	15.00	253.00	5.00
acsz-26y	Aleutian-Alaska-Cascadia	197.5498	55.1934	15.00	253.11	43.82
acsz-26z	Aleutian-Alaska-Cascadia	197.7620	54.7770	15.00	253.28	30.88
acsz-27a	Aleutian-Alaska-Cascadia	199.4340	54.5960	15.00	256.00	17.94
acsz-27b	Aleutian-Alaska-Cascadia	199.6200	54.1600	15.00	256.00	5.00
acsz-27x	Aleutian-Alaska-Cascadia	198.9736	55.8631	15.00	256.47	56.24
acsz-27y	Aleutian-Alaska-Cascadia	199.1454	55.4401	15.00	256.62	43.82
acsz-27z	Aleutian-Alaska-Cascadia	199.3135	55.0170	15.00	256.76	30.88
acsz-28a	Aleutian-Alaska-Cascadia	200.8820	54.8300	15.00	253.00	17.94
acsz-28b	Aleutian-Alaska-Cascadia	201.1080	54.4000	15.00	253.00	5.00
acsz-28x	Aleutian-Alaska-Cascadia	200.1929	56.0559	15.00	252.55	56.24
acsz-28y	Aleutian-Alaska-Cascadia	200.4167	55.6406	15.00	252.74	43.82
acsz-28z	Aleutian-Alaska-Cascadia	200.6360	55.2249	15.00	252.92	30.88

Table 7. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
acsz-29a	Aleutian-Alaska-Cascadia	202.2610	55.1330	15.00	247.00	17.94
acsz-29b	Aleutian-Alaska-Cascadia	202.5650	54.7200	15.00	247.00	5.00
acsz-29x	Aleutian-Alaska-Cascadia	201.2606	56.2861	15.00	245.70	56.24
acsz-29y	Aleutian-Alaska-Cascadia	201.5733	55.8888	15.00	245.96	43.82
acsz-29z	Aleutian-Alaska-Cascadia	201.8797	55.4908	15.00	246.21	30.88
acsz-30a	Aleutian-Alaska-Cascadia	203.6040	55.5090	15.00	240.00	17.94
acsz-30b	Aleutian-Alaska-Cascadia	203.9970	55.1200	15.00	240.00	5.00
acsz-30w	Aleutian-Alaska-Cascadia	201.9901	56.9855	15.00	239.52	69.12
acsz-30x	Aleutian-Alaska-Cascadia	202.3851	56.6094	15.00	239.85	56.24
acsz-30y	Aleutian-Alaska-Cascadia	202.7724	56.2320	15.00	240.17	43.82
acsz-30z	Aleutian-Alaska-Cascadia	203.1521	55.8534	15.00	240.49	30.88
acsz-31a	Aleutian-Alaska-Cascadia	204.8950	55.9700	15.00	236.00	17.94
acsz-31b	Aleutian-Alaska-Cascadia	205.3400	55.5980	15.00	236.00	5.00
acsz-31w	Aleutian-Alaska-Cascadia	203.0825	57.3740	15.00	234.54	69.12
acsz-31x	Aleutian-Alaska-Cascadia	203.5408	57.0182	15.00	234.93	56.24
acsz-31y	Aleutian-Alaska-Cascadia	203.9904	56.6607	15.00	235.30	43.82
acsz-31z	Aleutian-Alaska-Cascadia	204.4315	56.3016	15.00	235.67	30.88
acsz-32a	Aleutian-Alaska-Cascadia	206.2080	56.4730	15.00	236.00	17.94
acsz-32b	Aleutian-Alaska-Cascadia	206.6580	56.1000	15.00	236.00	5.00
acsz-32w	Aleutian-Alaska-Cascadia	204.4129	57.8908	15.00	234.32	69.12
acsz-32x	Aleutian-Alaska-Cascadia	204.8802	57.5358	15.00	234.72	56.24
acsz-32y	Aleutian-Alaska-Cascadia	205.3385	57.1792	15.00	235.10	43.82
acsz-32z	Aleutian-Alaska-Cascadia	205.7880	56.8210	15.00	235.48	30.88
acsz-33a	Aleutian-Alaska-Cascadia	207.5370	56.9750	15.00	236.00	17.94
acsz-33b	Aleutian-Alaska-Cascadia	207.9930	56.6030	15.00	236.00	5.00
acsz-33w	Aleutian-Alaska-Cascadia	205.7126	58.3917	15.00	234.24	69.12
acsz-33x	Aleutian-Alaska-Cascadia	206.1873	58.0371	15.00	234.64	56.24
acsz-33y	Aleutian-Alaska-Cascadia	206.6527	57.6808	15.00	235.03	43.82
acsz-33z	Aleutian-Alaska-Cascadia	207.1091	57.3227	15.00	235.41	30.88
acsz-34a	Aleutian-Alaska-Cascadia	208.9371	57.5124	15.00	236.00	17.94
acsz-34b	Aleutian-Alaska-Cascadia	209.4000	57.1400	15.00	236.00	5.00
acsz-34w	Aleutian-Alaska-Cascadia	206.9772	58.8804	15.00	233.47	69.12
acsz-34x	Aleutian-Alaska-Cascadia	207.4677	58.5291	15.00	233.88	56.24
acsz-34y	Aleutian-Alaska-Cascadia	207.9485	58.1760	15.00	234.29	43.82
acsz-34z	Aleutian-Alaska-Cascadia	208.4198	57.8213	15.00	234.69	30.88
acsz-35a	Aleutian-Alaska-Cascadia	210.2597	58.0441	15.00	230.00	17.94
acsz-35b	Aleutian-Alaska-Cascadia	210.8000	57.7000	15.00	230.00	5.00

Table 7. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
acsz-35w	Aleutian-Alaska-Cascadia	208.0204	59.3199	15.00	228.81	69.12
acsz-35x	Aleutian-Alaska-Cascadia	208.5715	58.9906	15.00	229.29	56.24
acsz-35y	Aleutian-Alaska-Cascadia	209.1122	58.6590	15.00	229.75	43.82
acsz-35z	Aleutian-Alaska-Cascadia	209.6425	58.3252	15.00	230.20	30.88
acsz-36a	Aleutian-Alaska-Cascadia	211.3249	58.6565	15.00	218.00	17.94
acsz-36b	Aleutian-Alaska-Cascadia	212.0000	58.3800	15.00	218.00	5.00
acsz-36w	Aleutian-Alaska-Cascadia	208.5003	59.5894	15.00	215.59	69.12
acsz-36x	Aleutian-Alaska-Cascadia	209.1909	59.3342	15.00	216.18	56.24
acsz-36y	Aleutian-Alaska-Cascadia	209.8711	59.0753	15.00	216.76	43.82
acsz-36z	Aleutian-Alaska-Cascadia	210.5412	58.8129	15.00	217.33	30.88
acsz-37a	Aleutian-Alaska-Cascadia	212.2505	59.2720	15.00	213.71	17.94
acsz-37b	Aleutian-Alaska-Cascadia	212.9519	59.0312	15.00	213.71	5.00
acsz-37x	Aleutian-Alaska-Cascadia	210.1726	60.0644	15.00	213.04	56.24
acsz-37y	Aleutian-Alaska-Cascadia	210.8955	59.8251	15.00	213.66	43.82
acsz-37z	Aleutian-Alaska-Cascadia	211.6079	59.5820	15.00	214.27	30.88
acsz-38a	Aleutian-Alaska-Cascadia	214.6555	60.1351	0.00	260.08	15.00
acsz-38b	Aleutian-Alaska-Cascadia	214.8088	59.6927	0.00	260.08	15.00
acsz-38y	Aleutian-Alaska-Cascadia	214.3737	60.9838	0.00	259.03	15.00
acsz-38z	Aleutian-Alaska-Cascadia	214.5362	60.5429	0.00	259.03	15.00
acsz-39a	Aleutian-Alaska-Cascadia	216.5607	60.2480	0.00	267.04	15.00
acsz-39b	Aleutian-Alaska-Cascadia	216.6068	59.7994	0.00	267.04	15.00
acsz-40a	Aleutian-Alaska-Cascadia	219.3069	59.7574	0.00	310.91	15.00
acsz-40b	Aleutian-Alaska-Cascadia	218.7288	59.4180	0.00	310.91	15.00
acsz-41a	Aleutian-Alaska-Cascadia	220.4832	59.3390	0.00	300.73	15.00
acsz-41b	Aleutian-Alaska-Cascadia	220.0382	58.9529	0.00	300.73	15.00
acsz-42a	Aleutian-Alaska-Cascadia	221.8835	58.9310	0.00	298.94	15.00
acsz-42b	Aleutian-Alaska-Cascadia	221.4671	58.5379	0.00	298.94	15.00
acsz-43a	Aleutian-Alaska-Cascadia	222.9711	58.6934	0.00	282.34	15.00
acsz-43b	Aleutian-Alaska-Cascadia	222.7887	58.2546	0.00	282.34	15.00
acsz-44a	Aleutian-Alaska-Cascadia	224.9379	57.9054	12.00	340.91	11.09
acsz-44b	Aleutian-Alaska-Cascadia	224.1596	57.7617	7.00	340.91	5.00
acsz-45a	Aleutian-Alaska-Cascadia	225.4994	57.1634	12.00	334.15	11.09
acsz-45b	Aleutian-Alaska-Cascadia	224.7740	56.9718	7.00	334.15	5.00
acsz-46a	Aleutian-Alaska-Cascadia	226.1459	56.3552	12.00	334.15	11.09
acsz-46b	Aleutian-Alaska-Cascadia	225.4358	56.1636	7.00	334.15	5.00
acsz-47a	Aleutian-Alaska-Cascadia	226.7731	55.5830	12.00	332.26	11.09
acsz-47b	Aleutian-Alaska-Cascadia	226.0887	55.3785	7.00	332.26	5.00

Table 7. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
acsz-48a	Aleutian-Alaska-Cascadia	227.4799	54.6763	12.00	339.40	11.09
acsz-48b	Aleutian-Alaska-Cascadia	226.7713	54.5217	7.00	339.40	5.00
acsz-49a	Aleutian-Alaska-Cascadia	227.9482	53.8155	12.00	341.17	11.09
acsz-49b	Aleutian-Alaska-Cascadia	227.2462	53.6737	7.00	341.17	5.00
acsz-50a	Aleutian-Alaska-Cascadia	228.3970	53.2509	12.00	324.51	11.09
acsz-50b	Aleutian-Alaska-Cascadia	227.8027	52.9958	7.00	324.51	5.00
acsz-51a	Aleutian-Alaska-Cascadia	229.1844	52.6297	12.00	318.36	11.09
acsz-51b	Aleutian-Alaska-Cascadia	228.6470	52.3378	7.00	318.36	5.00
acsz-52a	Aleutian-Alaska-Cascadia	230.0306	52.0768	12.00	310.85	11.09
acsz-52b	Aleutian-Alaska-Cascadia	229.5665	51.7445	7.00	310.85	5.00
acsz-53a	Aleutian-Alaska-Cascadia	231.1735	51.5258	12.00	310.85	11.09
acsz-53b	Aleutian-Alaska-Cascadia	230.7150	51.1935	7.00	310.85	5.00
acsz-54a	Aleutian-Alaska-Cascadia	232.2453	50.8809	12.00	314.11	11.09
acsz-54b	Aleutian-Alaska-Cascadia	231.7639	50.5655	7.00	314.11	5.00
acsz-55a	Aleutian-Alaska-Cascadia	233.3066	49.9032	12.00	333.71	11.09
acsz-55b	Aleutian-Alaska-Cascadia	232.6975	49.7086	7.00	333.71	5.00
acsz-56a	Aleutian-Alaska-Cascadia	234.0588	49.1702	11.00	315.00	12.82
acsz-56b	Aleutian-Alaska-Cascadia	233.5849	48.8584	9.00	315.00	5.00
acsz-57a	Aleutian-Alaska-Cascadia	234.9041	48.2596	11.00	341.00	12.82
acsz-57b	Aleutian-Alaska-Cascadia	234.2797	48.1161	9.00	341.00	5.00
acsz-58a	Aleutian-Alaska-Cascadia	235.3021	47.3812	11.00	344.00	12.82
acsz-58b	Aleutian-Alaska-Cascadia	234.6776	47.2597	9.00	344.00	5.00
acsz-59a	Aleutian-Alaska-Cascadia	235.6432	46.5082	11.00	345.00	12.82
acsz-59b	Aleutian-Alaska-Cascadia	235.0257	46.3941	9.00	345.00	5.00
acsz-60a	Aleutian-Alaska-Cascadia	235.8640	45.5429	11.00	356.00	12.82
acsz-60b	Aleutian-Alaska-Cascadia	235.2363	45.5122	9.00	356.00	5.00
acsz-61a	Aleutian-Alaska-Cascadia	235.9106	44.6227	11.00	359.00	12.82
acsz-61b	Aleutian-Alaska-Cascadia	235.2913	44.6150	9.00	359.00	5.00
acsz-62a	Aleutian-Alaska-Cascadia	235.9229	43.7245	11.00	359.00	12.82
acsz-62b	Aleutian-Alaska-Cascadia	235.3130	43.7168	9.00	359.00	5.00
acsz-63a	Aleutian-Alaska-Cascadia	236.0220	42.9020	11.00	350.00	12.82
acsz-63b	Aleutian-Alaska-Cascadia	235.4300	42.8254	9.00	350.00	5.00
acsz-64a	Aleutian-Alaska-Cascadia	235.9638	41.9818	11.00	345.00	12.82
acsz-64b	Aleutian-Alaska-Cascadia	235.3919	41.8677	9.00	345.00	5.00
acsz-65a	Aleutian-Alaska-Cascadia	236.2643	41.1141	11.00	345.00	12.82
acsz-65b	Aleutian-Alaska-Cascadia	235.7000	41.0000	9.00	345.00	5.00
acsz-238a	Aleutian-Alaska-Cascadia	213.2878	59.8406	15.00	236.83	17.94

Table 7. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
acsz-238y	Aleutian-Alaska-Cascadia	212.3424	60.5664	15.00	236.83	43.82
acsz-238z	Aleutian-Alaska-Cascadia	212.8119	60.2035	15.00	236.83	30.88

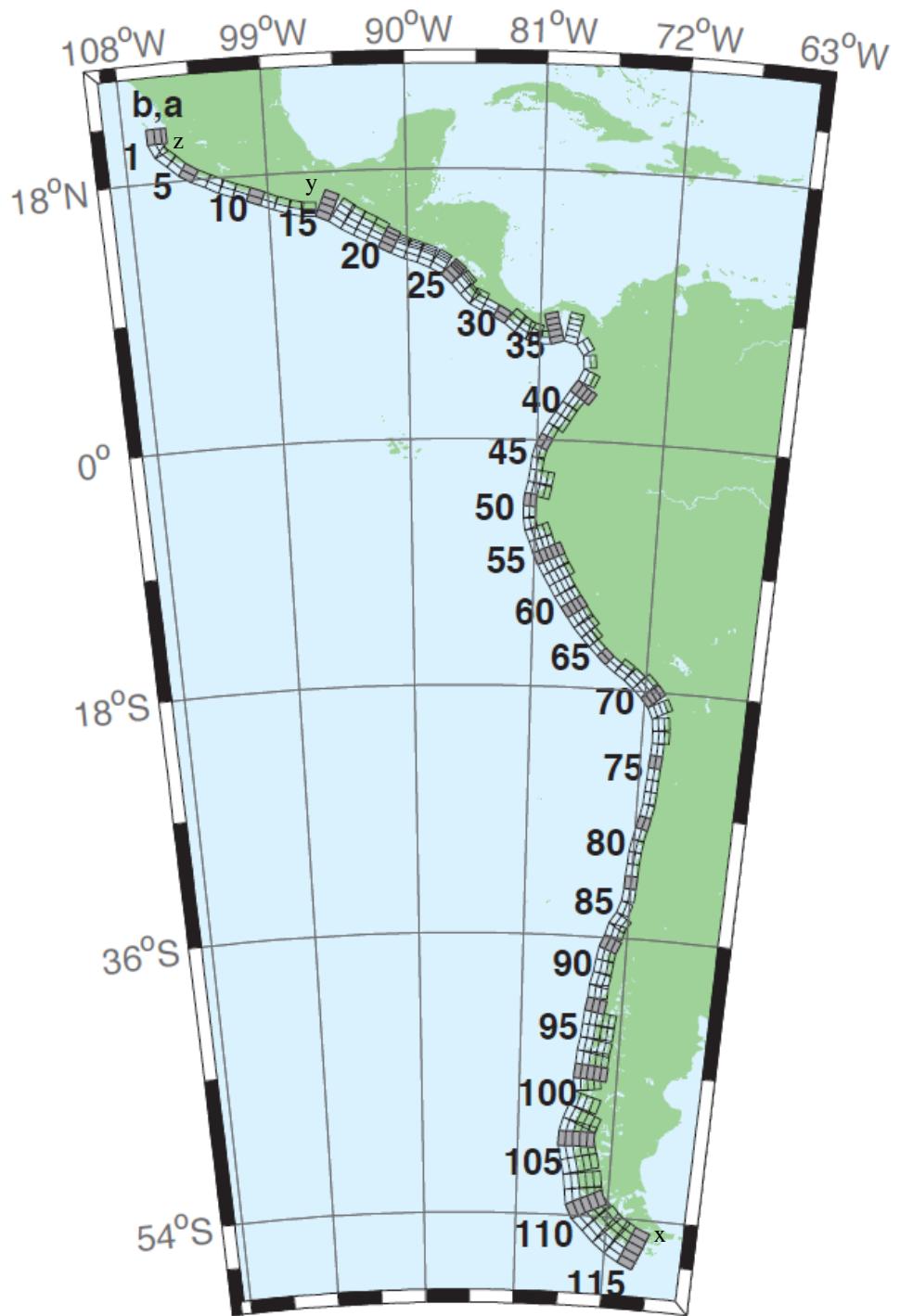


Figure 127. Central and South America Subduction Zone unit sources.

Table 8. Earthquake parameters for Central and South America Subduction Zone unit sources.

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
cssz-01a	Central and South America	254.4573	20.8170	19.00	358.97	15.40
cssz-01b	Central and South America	254.0035	20.8094	12.00	358.97	5.00
cssz-01z	Central and South America	254.7664	20.8222	50.00	358.97	31.67
cssz-02a	Central and South America	254.5765	20.2806	19.00	336.76	15.40
cssz-02b	Central and South America	254.1607	20.1130	12.00	336.76	5.00
cssz-03a	Central and South America	254.8789	19.8923	18.31	310.60	15.27
cssz-03b	Central and South America	254.5841	19.5685	11.85	310.60	5.00
cssz-04a	Central and South America	255.6167	19.2649	17.62	313.37	15.12
cssz-04b	Central and South America	255.3056	18.9537	11.68	313.37	5.00
cssz-05a	Central and South America	256.2240	18.8148	16.92	302.70	15.00
cssz-05b	Central and South America	255.9790	18.4532	11.54	302.70	5.00
cssz-06a	Central and South America	256.9425	18.4383	16.23	295.15	14.87
cssz-06b	Central and South America	256.7495	18.0479	11.38	295.15	5.00
cssz-07a	Central and South America	257.8137	18.0339	15.54	296.91	14.74
cssz-07b	Central and South America	257.6079	17.6480	11.23	296.91	5.00
cssz-08a	Central and South America	258.5779	17.7151	14.85	290.42	14.61
cssz-08b	Central and South America	258.4191	17.3082	11.08	290.42	5.00
cssz-09a	Central and South America	259.4578	17.4024	14.15	290.48	14.47
cssz-09b	Central and South America	259.2983	16.9944	10.92	290.48	5.00
cssz-10a	Central and South America	260.3385	17.0861	13.46	290.75	14.34
cssz-10b	Central and South America	260.1768	16.6776	10.77	290.75	5.00
cssz-11a	Central and South America	261.2255	16.7554	12.77	291.82	14.21
cssz-11b	Central and South America	261.0556	16.3487	10.62	291.82	5.00
cssz-12a	Central and South America	262.0561	16.4603	12.08	288.86	14.08
cssz-12b	Central and South America	261.9082	16.0447	10.46	288.86	5.00
cssz-13a	Central and South America	262.8638	16.2381	11.38	283.18	13.95
cssz-13b	Central and South America	262.7593	15.8094	10.31	283.18	5.00
cssz-14a	Central and South America	263.6066	16.1435	10.69	272.06	13.81
cssz-14b	Central and South America	263.5901	15.7024	10.15	272.06	5.00
cssz-15a	Central and South America	264.8259	15.8829	10.00	293.03	13.68
cssz-15b	Central and South America	264.6462	15.4758	10.00	293.03	5.00
cssz-15y	Central and South America	265.1865	16.6971	10.00	293.03	31.05
cssz-15z	Central and South America	265.0060	16.2900	10.00	293.03	22.36
cssz-16a	Central and South America	265.7928	15.3507	15.00	304.95	15.82
cssz-16b	Central and South America	265.5353	14.9951	12.50	304.95	5.00
cssz-16y	Central and South America	266.3092	16.0619	15.00	304.95	41.70

Table 8. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
cssz-16z	Central and South America	266.0508	15.7063	15.00	304.95	28.76
cssz-17a	Central and South America	266.4947	14.9019	20.00	299.52	17.94
cssz-17b	Central and South America	266.2797	14.5346	15.00	299.52	5.00
cssz-17y	Central and South America	266.9259	15.6365	20.00	299.52	52.14
cssz-17z	Central and South America	266.7101	15.2692	20.00	299.52	35.04
cssz-18a	Central and South America	267.2827	14.4768	21.50	298.01	17.94
cssz-18b	Central and South America	267.0802	14.1078	15.00	298.01	5.00
cssz-18y	Central and South America	267.6888	15.2148	21.50	298.01	54.59
cssz-18z	Central and South America	267.4856	14.8458	21.50	298.01	36.27
cssz-19a	Central and South America	268.0919	14.0560	23.00	297.64	17.94
cssz-19b	Central and South America	267.8943	13.6897	15.00	297.64	5.00
cssz-19y	Central and South America	268.4880	14.7886	23.00	297.64	57.01
cssz-19z	Central and South America	268.2898	14.4223	23.00	297.64	37.48
cssz-20a	Central and South America	268.8929	13.6558	24.00	296.23	17.94
cssz-20b	Central and South America	268.7064	13.2877	15.00	296.23	5.00
cssz-20y	Central and South America	269.1796	14.2206	45.50	296.23	73.94
cssz-20z	Central and South America	269.0362	13.9382	45.50	296.23	38.28
cssz-21a	Central and South America	269.6797	13.3031	25.00	292.65	17.94
cssz-21b	Central and South America	269.5187	12.9274	15.00	292.65	5.00
cssz-21x	Central and South America	269.8797	13.7690	68.00	292.65	131.79
cssz-21y	Central and South America	269.8130	13.6137	68.00	292.65	85.43
cssz-21z	Central and South America	269.7463	13.4584	68.00	292.65	39.07
cssz-22a	Central and South America	270.4823	13.0079	25.00	288.59	17.94
cssz-22b	Central and South America	270.3492	12.6221	15.00	288.59	5.00
cssz-22x	Central and South America	270.6476	13.4864	68.00	288.59	131.79
cssz-22y	Central and South America	270.5925	13.3269	68.00	288.59	85.43
cssz-22z	Central and South America	270.5374	13.1674	68.00	288.59	39.07
cssz-23a	Central and South America	271.3961	12.6734	25.00	292.45	17.94
cssz-23b	Central and South America	271.2369	12.2972	15.00	292.45	5.00
cssz-23x	Central and South America	271.5938	13.1399	68.00	292.45	131.79
cssz-23y	Central and South America	271.5279	12.9844	68.00	292.45	85.43
cssz-23z	Central and South America	271.4620	12.8289	68.00	292.45	39.07
cssz-24a	Central and South America	272.3203	12.2251	25.00	300.23	17.94
cssz-24b	Central and South America	272.1107	11.8734	15.00	300.23	5.00
cssz-24x	Central and South America	272.5917	12.6799	67.00	300.23	131.12
cssz-24y	Central and South America	272.5012	12.5283	67.00	300.23	85.10
cssz-24z	Central and South America	272.4107	12.3767	67.00	300.23	39.07

Table 8. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
cssz-25a	Central and South America	273.2075	11.5684	25.00	313.80	17.94
cssz-25b	Central and South America	272.9200	11.2746	15.00	313.80	5.00
cssz-25x	Central and South America	273.5950	11.9641	66.00	313.80	130.43
cssz-25y	Central and South America	273.4658	11.8322	66.00	313.80	84.75
cssz-25z	Central and South America	273.3366	11.7003	66.00	313.80	39.07
cssz-26a	Central and South America	273.8943	10.8402	25.00	320.42	17.94
cssz-26b	Central and South America	273.5750	10.5808	15.00	320.42	5.00
cssz-26x	Central and South America	274.3246	11.1894	66.00	320.42	130.43
cssz-26y	Central and South America	274.1811	11.0730	66.00	320.42	84.75
cssz-26z	Central and South America	274.0377	10.9566	66.00	320.42	39.07
cssz-27a	Central and South America	274.4569	10.2177	25.00	316.10	17.94
cssz-27b	Central and South America	274.1590	9.9354	15.00	316.10	5.00
cssz-27z	Central and South America	274.5907	10.3444	66.00	316.10	39.07
cssz-28a	Central and South America	274.9586	9.8695	22.00	297.10	14.54
cssz-28b	Central and South America	274.7661	9.4988	11.00	297.10	5.00
cssz-28z	Central and South America	275.1118	10.1643	42.50	297.10	33.27
cssz-29a	Central and South America	275.7686	9.4789	19.00	296.60	11.09
cssz-29b	Central and South America	275.5759	9.0992	7.00	296.60	5.00
cssz-30a	Central and South America	276.6346	8.9973	19.00	302.25	9.36
cssz-30b	Central and South America	276.4053	8.6381	5.00	302.25	5.00
cssz-31a	Central and South America	277.4554	8.4152	19.00	309.05	7.62
cssz-31b	Central and South America	277.1851	8.0854	3.00	309.05	5.00
cssz-31z	Central and South America	277.7260	8.7450	19.00	309.05	23.90
cssz-32a	Central and South America	278.1112	7.9425	18.67	302.97	8.49
cssz-32b	Central and South America	277.8775	7.5855	4.00	302.97	5.00
cssz-32z	Central and South America	278.3407	8.2927	21.67	302.97	24.49
cssz-33a	Central and South America	278.7082	7.6620	18.33	287.56	10.23
cssz-33b	Central and South America	278.5785	7.2555	6.00	287.56	5.00
cssz-33z	Central and South America	278.8328	8.0522	24.33	287.56	25.95
cssz-34a	Central and South America	279.3184	7.5592	18.00	269.48	17.94
cssz-34b	Central and South America	279.3223	7.1320	15.00	269.48	5.00
cssz-35a	Central and South America	280.0039	7.6543	17.67	255.90	14.54
cssz-35b	Central and South America	280.1090	7.2392	11.00	255.90	5.00
cssz-35x	Central and South America	279.7156	8.7898	29.67	255.90	79.22
cssz-35y	Central and South America	279.8118	8.4113	29.67	255.90	54.47
cssz-35z	Central and South America	279.9079	8.0328	29.67	255.90	29.72

Table 8. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
cssz-36a	Central and South America	281.2882	7.6778	17.33	282.48	11.09
cssz-36b	Central and South America	281.1948	7.2592	7.00	282.48	5.00
cssz-36x	Central and South America	281.5368	8.7896	32.33	282.48	79.47
cssz-36y	Central and South America	281.4539	8.4190	32.33	282.48	52.73
cssz-36z	Central and South America	281.3710	8.0484	32.33	282.48	25.99
cssz-37a	Central and South America	282.5252	6.8289	17.00	326.91	10.23
cssz-37b	Central and South America	282.1629	6.5944	6.00	326.91	5.00
cssz-38a	Central and South America	282.9469	5.5973	17.00	355.37	10.23
cssz-38b	Central and South America	282.5167	5.5626	6.00	355.37	5.00
cssz-39a	Central and South America	282.7236	4.3108	17.00	24.13	10.23
cssz-39b	Central and South America	282.3305	4.4864	6.00	24.13	5.00
cssz-39z	Central and South America	283.0603	4.1604	35.00	24.13	24.85
cssz-40a	Central and South America	282.1940	3.3863	17.00	35.28	10.23
cssz-40b	Central and South America	281.8427	3.6344	6.00	35.28	5.00
cssz-40y	Central and South America	282.7956	2.9613	35.00	35.28	53.52
cssz-40z	Central and South America	282.4948	3.1738	35.00	35.28	24.85
cssz-41a	Central and South America	281.6890	2.6611	17.00	34.27	10.23
cssz-41b	Central and South America	281.3336	2.9030	6.00	34.27	5.00
cssz-41z	Central and South America	281.9933	2.4539	35.00	34.27	24.85
cssz-42a	Central and South America	281.2266	1.9444	17.00	31.29	10.23
cssz-42b	Central and South America	280.8593	2.1675	6.00	31.29	5.00
cssz-42z	Central and South America	281.5411	1.7533	35.00	31.29	24.85
cssz-43a	Central and South America	280.7297	1.1593	17.00	33.30	10.23
cssz-43b	Central and South America	280.3706	1.3951	6.00	33.30	5.00
cssz-43z	Central and South America	281.0373	0.9573	35.00	33.30	24.85
cssz-44a	Central and South America	280.3018	0.4491	17.00	28.80	10.23
cssz-44b	Central and South America	279.9254	0.6560	6.00	28.80	5.00
cssz-45a	Central and South America	279.9083	-0.3259	10.00	26.91	8.49
cssz-45b	Central and South America	279.5139	-0.1257	4.00	26.91	5.00
cssz-46a	Central and South America	279.6461	-0.9975	10.00	15.76	8.49
cssz-46b	Central and South America	279.2203	-0.8774	4.00	15.76	5.00
cssz-47a	Central and South America	279.4972	-1.7407	10.00	6.90	8.49
cssz-47b	Central and South America	279.0579	-1.6876	4.00	6.90	5.00
cssz-48a	Central and South America	279.3695	-2.6622	10.00	8.96	8.49
cssz-48b	Central and South America	278.9321	-2.5933	4.00	8.96	5.00
cssz-48y	Central and South America	280.2444	-2.8000	10.00	8.96	25.85
cssz-48z	Central and South America	279.8070	-2.7311	10.00	8.96	17.17

Table 8. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
cssz-49a	Central and South America	279.1852	-3.6070	10.00	13.15	8.49
cssz-49b	Central and South America	278.7536	-3.5064	4.00	13.15	5.00
cssz-49y	Central and South America	280.0486	-3.8082	10.00	13.15	25.85
cssz-49z	Central and South America	279.6169	-3.7076	10.00	13.15	17.17
cssz-50a	Central and South America	279.0652	-4.3635	10.33	4.78	9.64
cssz-50b	Central and South America	278.6235	-4.3267	5.33	4.78	5.00
cssz-51a	Central and South America	279.0349	-5.1773	10.67	359.43	10.81
cssz-51b	Central and South America	278.5915	-5.1817	6.67	359.43	5.00
cssz-52a	Central and South America	279.1047	-5.9196	11.00	349.75	11.96
cssz-52b	Central and South America	278.6685	-5.9981	8.00	349.75	5.00
cssz-53a	Central and South America	279.3044	-6.6242	10.25	339.21	11.74
cssz-53b	Central and South America	278.8884	-6.7811	7.75	339.21	5.00
cssz-53y	Central and South America	280.1024	-6.3232	19.25	339.21	37.12
cssz-53z	Central and South America	279.7035	-6.4737	19.25	339.21	20.64
cssz-54a	Central and South America	279.6256	-7.4907	9.50	340.78	11.53
cssz-54b	Central and South America	279.2036	-7.6365	7.50	340.78	5.00
cssz-54y	Central and South America	280.4267	-7.2137	20.50	340.78	37.29
cssz-54z	Central and South America	280.0262	-7.3522	20.50	340.78	19.78
cssz-55a	Central and South America	279.9348	-8.2452	8.75	335.38	11.74
cssz-55b	Central and South America	279.5269	-8.4301	7.75	335.38	5.00
cssz-55x	Central and South America	281.0837	-7.7238	21.75	335.38	56.40
cssz-55y	Central and South America	280.7009	-7.8976	21.75	335.38	37.88
cssz-55z	Central and South America	280.3180	-8.0714	21.75	335.38	19.35
cssz-56a	Central and South America	280.3172	-8.9958	8.00	331.62	11.09
cssz-56b	Central and South America	279.9209	-9.2072	7.00	331.62	5.00
cssz-56x	Central and South America	281.4212	-8.4063	23.00	331.62	57.13
cssz-56y	Central and South America	281.0534	-8.6028	23.00	331.62	37.59
cssz-56z	Central and South America	280.6854	-8.7993	23.00	331.62	18.05
cssz-57a	Central and South America	280.7492	-9.7356	8.60	328.71	10.75
cssz-57b	Central and South America	280.3640	-9.9663	6.60	328.71	5.00
cssz-57x	Central and South America	281.8205	-9.0933	23.40	328.71	57.94
cssz-57y	Central and South America	281.4636	-9.3074	23.40	328.71	38.08
cssz-57z	Central and South America	281.1065	-9.5215	23.40	328.71	18.22
cssz-58a	Central and South America	281.2275	-10.5350	9.20	330.52	10.40
cssz-58b	Central and South America	280.8348	-10.7532	6.20	330.52	5.00
cssz-58y	Central and South America	281.9548	-10.1306	23.80	330.52	38.57
cssz-58z	Central and South America	281.5913	-10.3328	23.80	330.52	18.39

Table 8. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
cssz-59a	Central and South America	281.6735	-11.2430	9.80	326.24	10.05
cssz-59b	Central and South America	281.2982	-11.4890	5.80	326.24	5.00
cssz-59y	Central and South America	282.3675	-10.7876	24.20	326.24	39.06
cssz-59z	Central and South America	282.0206	-11.0153	24.20	326.24	18.56
cssz-60a	Central and South America	282.1864	-11.9946	10.40	326.50	9.71
cssz-60b	Central and South America	281.8096	-12.2384	5.40	326.50	5.00
cssz-60y	Central and South America	282.8821	-11.5438	24.60	326.50	39.55
cssz-60z	Central and South America	282.5344	-11.7692	24.60	326.50	18.73
cssz-61a	Central and South America	282.6944	-12.7263	11.00	325.47	9.36
cssz-61b	Central and South America	282.3218	-12.9762	5.00	325.47	5.00
cssz-61y	Central and South America	283.3814	-12.2649	25.00	325.47	40.03
cssz-61z	Central and South America	283.0381	-12.4956	25.00	325.47	18.90
cssz-62a	Central and South America	283.1980	-13.3556	11.00	318.96	9.79
cssz-62b	Central and South America	282.8560	-13.6451	5.50	318.96	5.00
cssz-62y	Central and South America	283.8178	-12.8300	27.00	318.96	42.03
cssz-62z	Central and South America	283.5081	-13.0928	27.00	318.96	19.33
cssz-63a	Central and South America	283.8032	-14.0147	11.00	317.85	10.23
cssz-63b	Central and South America	283.4661	-14.3106	6.00	317.85	5.00
cssz-63z	Central and South America	284.1032	-13.7511	29.00	317.85	19.77
cssz-64a	Central and South America	284.4144	-14.6482	13.00	315.68	11.96
cssz-64b	Central and South America	284.0905	-14.9540	8.00	315.68	5.00
cssz-65a	Central and South America	285.0493	-15.2554	15.00	313.23	13.68
cssz-65b	Central and South America	284.7411	-15.5715	10.00	313.23	5.00
cssz-66a	Central and South America	285.6954	-15.7816	14.50	307.67	13.68
cssz-66b	Central and South America	285.4190	-16.1258	10.00	307.67	5.00
cssz-67a	Central and South America	286.4127	-16.2781	14.00	304.30	13.68
cssz-67b	Central and South America	286.1566	-16.6381	10.00	304.30	5.00
cssz-67z	Central and South America	286.6552	-15.9365	23.00	304.30	25.78
cssz-68a	Central and South America	287.2481	-16.9016	14.00	311.81	13.68
cssz-68b	Central and South America	286.9442	-17.2264	10.00	311.81	5.00
cssz-68z	Central and South America	287.5291	-16.6007	26.00	311.81	25.78
cssz-69a	Central and South America	287.9724	-17.5502	14.00	314.88	13.68
cssz-69b	Central and South America	287.6496	-17.8590	10.00	314.88	5.00
cssz-69y	Central and South America	288.5530	-16.9934	29.00	314.88	50.02
cssz-69z	Central and South America	288.2629	-17.2718	29.00	314.88	25.78
cssz-70a	Central and South America	288.6731	-18.2747	14.00	320.37	13.25
cssz-70b	Central and South America	288.3193	-18.5527	9.50	320.37	5.00

Table 8. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
cssz-70y	Central and South America	289.3032	-17.7785	30.00	320.37	50.35
cssz-70z	Central and South America	288.9884	-18.0266	30.00	320.37	25.35
cssz-71a	Central and South America	289.3089	-19.1854	14.00	333.19	12.82
cssz-71b	Central and South America	288.8968	-19.3820	9.00	333.19	5.00
cssz-71y	Central and South America	290.0357	-18.8382	31.00	333.19	50.67
cssz-71z	Central and South America	289.6725	-19.0118	31.00	333.19	24.92
cssz-72a	Central and South America	289.6857	-20.3117	14.00	352.39	12.54
cssz-72b	Central and South America	289.2250	-20.3694	8.67	352.39	5.00
cssz-72z	Central and South America	290.0882	-20.2613	32.00	352.39	24.63
cssz-73a	Central and South America	289.7731	-21.3061	14.00	358.94	12.24
cssz-73b	Central and South America	289.3053	-21.3142	8.33	358.94	5.00
cssz-73z	Central and South America	290.1768	-21.2991	33.00	358.94	24.34
cssz-74a	Central and South America	289.7610	-22.2671	14.00	3.06	11.96
cssz-74b	Central and South America	289.2909	-22.2438	8.00	3.06	5.00
cssz-75a	Central and South America	289.6982	-23.1903	14.09	4.83	11.96
cssz-75b	Central and South America	289.2261	-23.1536	8.00	4.83	5.00
cssz-76a	Central and South America	289.6237	-24.0831	14.18	4.67	11.96
cssz-76b	Central and South America	289.1484	-24.0476	8.00	4.67	5.00
cssz-77a	Central and South America	289.5538	-24.9729	14.27	4.30	11.96
cssz-77b	Central and South America	289.0750	-24.9403	8.00	4.30	5.00
cssz-78a	Central and South America	289.4904	-25.8621	14.36	3.86	11.96
cssz-78b	Central and South America	289.0081	-25.8328	8.00	3.86	5.00
cssz-79a	Central and South America	289.3491	-26.8644	14.45	11.34	11.96
cssz-79b	Central and South America	288.8712	-26.7789	8.00	11.34	5.00
cssz-80a	Central and South America	289.1231	-27.7826	14.54	14.16	11.96
cssz-80b	Central and South America	288.6469	-27.6762	8.00	14.16	5.00
cssz-81a	Central and South America	288.8943	-28.6409	14.63	13.19	11.96
cssz-81b	Central and South America	288.4124	-28.5417	8.00	13.19	5.00
cssz-82a	Central and South America	288.7113	-29.4680	14.72	9.68	11.96
cssz-82b	Central and South America	288.2196	-29.3950	8.00	9.68	5.00
cssz-83a	Central and South America	288.5944	-30.2923	14.81	5.36	11.96
cssz-83b	Central and South America	288.0938	-30.2517	8.00	5.36	5.00
cssz-84a	Central and South America	288.5223	-31.1639	14.90	3.80	11.96
cssz-84b	Central and South America	288.0163	-31.1351	8.00	3.80	5.00
cssz-85a	Central and South America	288.4748	-32.0416	15.00	2.55	11.96
cssz-85b	Central and South America	287.9635	-32.0223	8.00	2.55	5.00
cssz-86a	Central and South America	288.3901	-33.0041	15.00	7.01	11.96

Table 8. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
cssz-86b	Central and South America	287.8768	-32.9512	8.00	7.01	5.00
cssz-87a	Central and South America	288.1050	-34.0583	15.00	19.40	11.96
cssz-87b	Central and South America	287.6115	-33.9142	8.00	19.40	5.00
cssz-88a	Central and South America	287.5309	-35.0437	15.00	32.81	11.96
cssz-88b	Central and South America	287.0862	-34.8086	8.00	32.81	5.00
cssz-88z	Central and South America	287.9308	-35.2545	30.00	32.81	24.90
cssz-89a	Central and South America	287.2380	-35.5993	16.67	14.52	11.96
cssz-89b	Central and South America	286.7261	-35.4914	8.00	14.52	5.00
cssz-89z	Central and South America	287.7014	-35.6968	30.00	14.52	26.30
cssz-90a	Central and South America	286.8442	-36.5645	18.33	22.64	11.96
cssz-90b	Central and South America	286.3548	-36.4004	8.00	22.64	5.00
cssz-90z	Central and South America	287.2916	-36.7142	30.00	22.64	27.68
cssz-91a	Central and South America	286.5925	-37.2488	20.00	10.90	11.96
cssz-91b	Central and South America	286.0721	-37.1690	8.00	10.90	5.00
cssz-91z	Central and South America	287.0726	-37.3224	30.00	10.90	29.06
cssz-92a	Central and South America	286.4254	-38.0945	20.00	8.23	11.96
cssz-92b	Central and South America	285.8948	-38.0341	8.00	8.23	5.00
cssz-92z	Central and South America	286.9303	-38.1520	26.67	8.23	29.06
cssz-93a	Central and South America	286.2047	-39.0535	20.00	13.46	11.96
cssz-93b	Central and South America	285.6765	-38.9553	8.00	13.46	5.00
cssz-93z	Central and South America	286.7216	-39.1495	23.33	13.46	29.06
cssz-94a	Central and South America	286.0772	-39.7883	20.00	3.40	11.96
cssz-94b	Central and South America	285.5290	-39.7633	8.00	3.40	5.00
cssz-94z	Central and South America	286.6255	-39.8133	20.00	3.40	29.06
cssz-95a	Central and South America	285.9426	-40.7760	20.00	9.84	11.96
cssz-95b	Central and South America	285.3937	-40.7039	8.00	9.84	5.00
cssz-95z	Central and South America	286.4921	-40.8481	20.00	9.84	29.06
cssz-96a	Central and South America	285.7839	-41.6303	20.00	7.60	11.96
cssz-96b	Central and South America	285.2245	-41.5745	8.00	7.60	5.00
cssz-96x	Central and South America	287.4652	-41.7977	20.00	7.60	63.26
cssz-96y	Central and South America	286.9043	-41.7419	20.00	7.60	46.16
cssz-96z	Central and South America	286.3439	-41.6861	20.00	7.60	29.06
cssz-97a	Central and South America	285.6695	-42.4882	20.00	5.30	11.96
cssz-97b	Central and South America	285.0998	-42.4492	8.00	5.30	5.00
cssz-97x	Central and South America	287.3809	-42.6052	20.00	5.30	63.26
cssz-97y	Central and South America	286.8101	-42.5662	20.00	5.30	46.16
cssz-97z	Central and South America	286.2396	-42.5272	20.00	5.30	29.06

Table 8. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
cssz-98a	Central and South America	285.5035	-43.4553	20.00	10.53	11.96
cssz-98b	Central and South America	284.9322	-43.3782	8.00	10.53	5.00
cssz-98x	Central and South America	287.2218	-43.6866	20.00	10.53	63.26
cssz-98y	Central and South America	286.6483	-43.6095	20.00	10.53	46.16
cssz-98z	Central and South America	286.0755	-43.5324	20.00	10.53	29.06
cssz-99a	Central and South America	285.3700	-44.2595	20.00	4.86	11.96
cssz-99b	Central and South America	284.7830	-44.2237	8.00	4.86	5.00
cssz-99x	Central and South America	287.1332	-44.3669	20.00	4.86	63.26
cssz-99y	Central and South America	286.5451	-44.3311	20.00	4.86	46.16
cssz-99z	Central and South America	285.9574	-44.2953	20.00	4.86	29.06
cssz-100a	Central and South America	285.2713	-45.1664	20.00	5.68	11.96
cssz-100b	Central and South America	284.6758	-45.1246	8.00	5.68	5.00
cssz-100x	Central and South America	287.0603	-45.2918	20.00	5.68	63.26
cssz-100y	Central and South America	286.4635	-45.2500	20.00	5.68	46.16
cssz-100z	Central and South America	285.8672	-45.2082	20.00	5.68	29.06
cssz-101a	Central and South America	285.3080	-45.8607	20.00	352.58	9.36
cssz-101b	Central and South America	284.7067	-45.9152	5.00	352.58	5.00
cssz-101y	Central and South America	286.5089	-45.7517	20.00	352.58	43.56
cssz-101z	Central and South America	285.9088	-45.8062	20.00	352.58	26.46
cssz-102a	Central and South America	285.2028	-47.1185	5.00	17.72	9.36
cssz-102b	Central and South America	284.5772	-46.9823	5.00	17.72	5.00
cssz-102y	Central and South America	286.4588	-47.3909	5.00	17.72	18.07
cssz-102z	Central and South America	285.8300	-47.2547	5.00	17.72	13.72
cssz-103a	Central and South America	284.7075	-48.0396	7.50	23.37	11.53
cssz-103b	Central and South America	284.0972	-47.8630	7.50	23.37	5.00
cssz-103x	Central and South America	286.5511	-48.5694	7.50	23.37	31.11
cssz-103y	Central and South America	285.9344	-48.3928	7.50	23.37	24.58
cssz-103z	Central and South America	285.3199	-48.2162	7.50	23.37	18.05
cssz-104a	Central and South America	284.3440	-48.7597	10.00	14.87	13.68
cssz-104b	Central and South America	283.6962	-48.6462	10.00	14.87	5.00
cssz-104x	Central and South America	286.2962	-49.1002	10.00	14.87	39.73
cssz-104y	Central and South America	285.6440	-48.9867	10.00	14.87	31.05
cssz-104z	Central and South America	284.9933	-48.8732	10.00	14.87	22.36
cssz-105a	Central and South America	284.2312	-49.4198	9.67	0.25	13.40
cssz-105b	Central and South America	283.5518	-49.4179	9.67	0.25	5.00
cssz-105x	Central and South America	286.2718	-49.4255	9.67	0.25	38.59
cssz-105y	Central and South America	285.5908	-49.4236	9.67	0.25	30.20

Table 8. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
cssz-105z	Central and South America	284.9114	-49.4217	9.67	0.25	21.80
cssz-106a	Central and South America	284.3730	-50.1117	9.25	347.50	13.04
cssz-106b	Central and South America	283.6974	-50.2077	9.25	347.50	5.00
cssz-106x	Central and South America	286.3916	-49.8238	9.25	347.50	37.15
cssz-106y	Central and South America	285.7201	-49.9198	9.25	347.50	29.11
cssz-106z	Central and South America	285.0472	-50.0157	9.25	347.50	21.07
cssz-107a	Central and South America	284.7130	-50.9714	9.00	346.48	12.82
cssz-107b	Central and South America	284.0273	-51.0751	9.00	346.48	5.00
cssz-107x	Central and South America	286.7611	-50.6603	9.00	346.48	36.29
cssz-107y	Central and South America	286.0799	-50.7640	9.00	346.48	28.47
cssz-107z	Central and South America	285.3972	-50.8677	9.00	346.48	20.64
cssz-108a	Central and South America	285.0378	-51.9370	8.67	352.01	12.54
cssz-108b	Central and South America	284.3241	-51.9987	8.67	352.01	5.00
cssz-108x	Central and South America	287.1729	-51.7519	8.67	352.01	35.15
cssz-108y	Central and South America	286.4622	-51.8136	8.67	352.01	27.61
cssz-108z	Central and South America	285.7505	-51.8753	8.67	352.01	20.07
cssz-109a	Central and South America	285.2635	-52.8439	8.33	353.08	12.24
cssz-109b	Central and South America	284.5326	-52.8974	8.33	353.08	5.00
cssz-109x	Central and South America	287.4508	-52.6834	8.33	353.08	33.97
cssz-109y	Central and South America	286.7226	-52.7369	8.33	353.08	26.73
cssz-109z	Central and South America	285.9935	-52.7904	8.33	353.08	19.49
cssz-110a	Central and South America	285.5705	-53.4139	8.00	334.19	11.96
cssz-110b	Central and South America	284.8972	-53.6076	8.00	334.19	5.00
cssz-110x	Central and South America	287.5724	-52.8328	8.00	334.19	32.83
cssz-110y	Central and South America	286.9081	-53.0265	8.00	334.19	25.88
cssz-110z	Central and South America	286.2408	-53.2202	8.00	334.19	18.92
cssz-111a	Central and South America	286.1627	-53.8749	8.00	313.83	11.96
cssz-111b	Central and South America	285.6382	-54.1958	8.00	313.83	5.00
cssz-111x	Central and South America	287.7124	-52.9122	8.00	313.83	32.83
cssz-111y	Central and South America	287.1997	-53.2331	8.00	313.83	25.88
cssz-111z	Central and South America	286.6832	-53.5540	8.00	313.83	18.92
cssz-112a	Central and South America	287.3287	-54.5394	8.00	316.39	11.96
cssz-112b	Central and South America	286.7715	-54.8462	8.00	316.39	5.00
cssz-112x	Central and South America	288.9756	-53.6190	8.00	316.39	32.83
cssz-112y	Central and South America	288.4307	-53.9258	8.00	316.39	25.88
cssz-112z	Central and South America	287.8817	-54.2326	8.00	316.39	18.92
cssz-113a	Central and South America	288.3409	-55.0480	8.00	307.64	11.96

Table 8. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
cssz-113b	Central and South America	287.8647	-55.4002	8.00	307.64	5.00
cssz-113x	Central and South America	289.7450	-53.9914	8.00	307.64	32.83
cssz-113y	Central and South America	289.2810	-54.3436	8.00	307.64	25.88
cssz-113z	Central and South America	288.8130	-54.6958	8.00	307.64	18.92
cssz-114a	Central and South America	289.5342	-55.5026	8.00	301.48	11.96
cssz-114b	Central and South America	289.1221	-55.8819	8.00	301.48	5.00
cssz-114x	Central and South America	290.7472	-54.3647	8.00	301.48	32.83
cssz-114y	Central and South America	290.3467	-54.7440	8.00	301.48	25.88
cssz-114z	Central and South America	289.9424	-55.1233	8.00	301.48	18.92
cssz-115a	Central and South America	290.7682	-55.8485	8.00	292.70	11.96
cssz-115b	Central and South America	290.4608	-56.2588	8.00	292.70	5.00
cssz-115x	Central and South America	291.6714	-54.6176	8.00	292.70	32.83
cssz-115y	Central and South America	291.3734	-55.0279	8.00	292.70	25.88
cssz-115z	Central and South America	291.0724	-55.4382	8.00	292.70	18.92

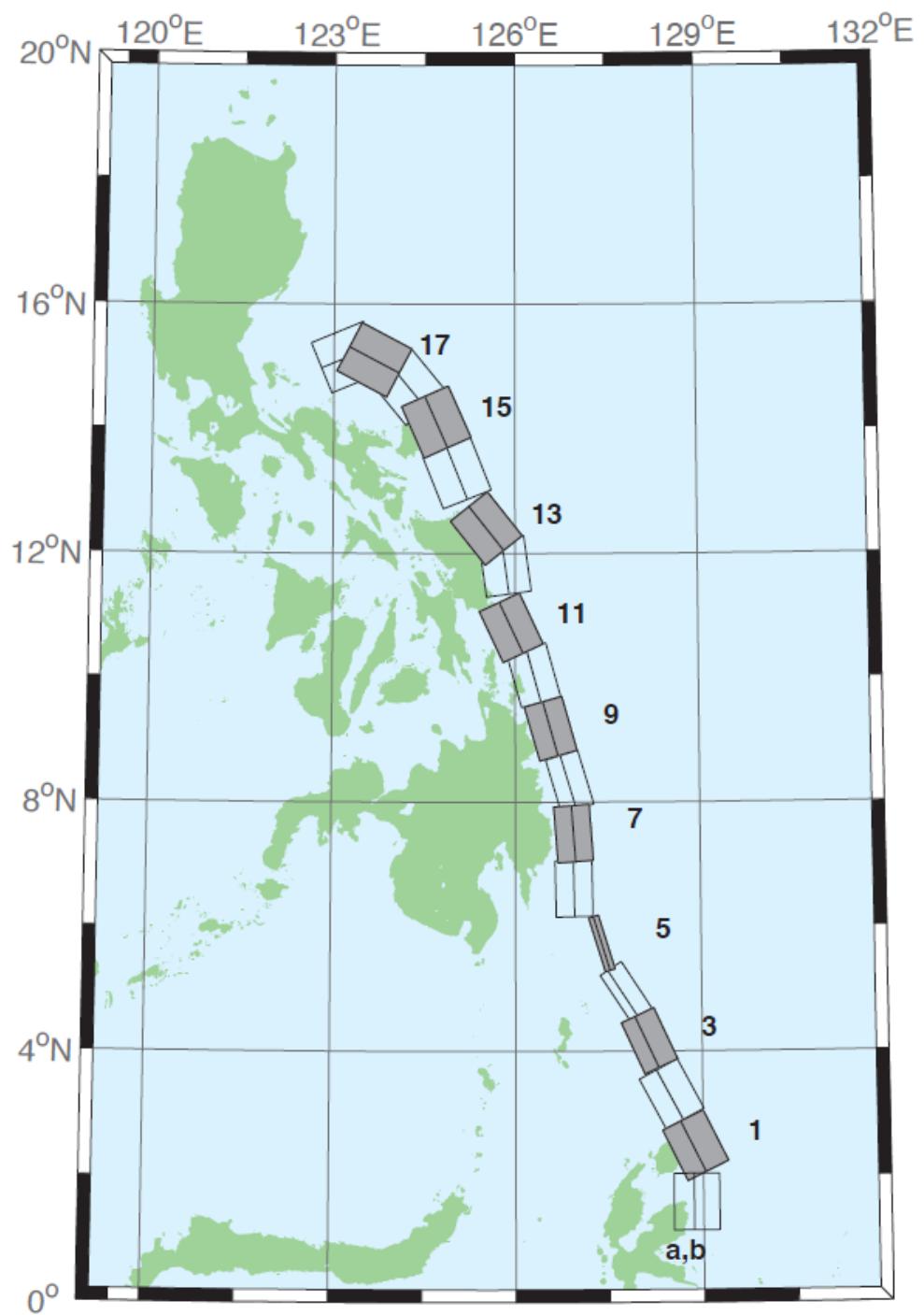


Figure 128. East Philippines Subduction Zone unit sources.

Table 9. Earthquake parameters for East Philippines Subduction Zone unit sources.

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
epsz-00a	East Philippines	128.5264	1.5930	44.00	180.00	26.92
epsz-00b	East Philippines	128.8496	1.5930	26.00	180.00	5.00
epsz-01a	East Philippines	128.5521	2.3289	44.20	153.61	27.62
epsz-01b	East Philippines	128.8408	2.4720	26.90	153.61	5.00
epsz-02a	East Philippines	128.1943	3.1508	45.90	151.93	32.44
epsz-02b	East Philippines	128.4706	3.2979	32.80	151.93	5.35
epsz-03a	East Philippines	127.8899	4.0428	57.30	155.22	40.22
epsz-03b	East Philippines	128.1108	4.1445	42.70	155.22	6.31
epsz-04a	East Philippines	127.6120	4.8371	71.40	146.84	48.25
epsz-04b	East Philippines	127.7324	4.9155	54.80	146.84	7.39
epsz-05a	East Philippines	127.3173	5.7040	79.90	162.87	57.40
epsz-05b	East Philippines	127.3930	5.7272	79.40	162.87	8.25
epsz-06a	East Philippines	126.6488	6.6027	48.60	178.89	45.09
epsz-06b	East Philippines	126.9478	6.6085	48.60	178.89	7.58
epsz-07a	East Philippines	126.6578	7.4711	50.70	175.76	45.52
epsz-07b	East Philippines	126.9439	7.4921	50.70	175.76	6.83
epsz-08a	East Philippines	126.6227	8.2456	56.70	163.31	45.60
epsz-08b	East Philippines	126.8614	8.3164	48.90	163.31	7.92
epsz-09a	East Philippines	126.2751	9.0961	47.00	164.09	43.59
epsz-09b	East Philippines	126.5735	9.1801	44.90	164.09	8.30
epsz-10a	East Philippines	125.9798	9.9559	43.10	164.46	42.25
epsz-10b	East Philippines	126.3007	10.0438	43.10	164.46	8.09
epsz-11a	East Philippines	125.6079	10.6557	37.80	154.97	38.29
epsz-11b	East Philippines	125.9353	10.8059	37.80	154.97	7.64
epsz-12a	East Philippines	125.4697	11.7452	36.00	172.14	37.01
epsz-12b	East Philippines	125.8374	11.7949	36.00	172.14	7.62
epsz-13a	East Philippines	125.2238	12.1670	32.40	141.53	33.87
epsz-13b	East Philippines	125.5278	12.4029	32.40	141.53	7.08
epsz-14a	East Philippines	124.6476	13.1365	23.00	158.23	25.92
epsz-14b	East Philippines	125.0421	13.2898	23.00	158.23	6.38
epsz-15a	East Philippines	124.3107	13.9453	24.10	156.12	26.51
epsz-15b	East Philippines	124.6973	14.1113	24.10	156.12	6.09
epsz-16a	East Philippines	123.8998	14.4025	19.50	140.32	21.69
epsz-16b	East Philippines	124.2366	14.6728	19.50	140.32	5.00
epsz-17a	East Philippines	123.4604	14.7222	15.30	117.58	18.19
epsz-17b	East Philippines	123.6682	15.1062	15.30	117.58	5.00

Table 9. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
epsz-18a	East Philippines	123.3946	14.7462	15.00	67.40	17.94
epsz-18b	East Philippines	123.2219	15.1467	15.00	67.40	5.00
epsz-19a	East Philippines	121.3638	15.7400	15.00	189.63	17.94
epsz-19b	East Philippines	121.8082	15.6674	15.00	189.63	5.00
epsz-20a	East Philippines	121.6833	16.7930	15.00	203.26	17.94
epsz-20b	East Philippines	122.0994	16.6216	15.00	203.26	5.00
epsz-21a	East Philippines	121.8279	17.3742	15.00	184.19	17.94
epsz-21b	East Philippines	122.2814	17.3425	15.00	184.19	5.00

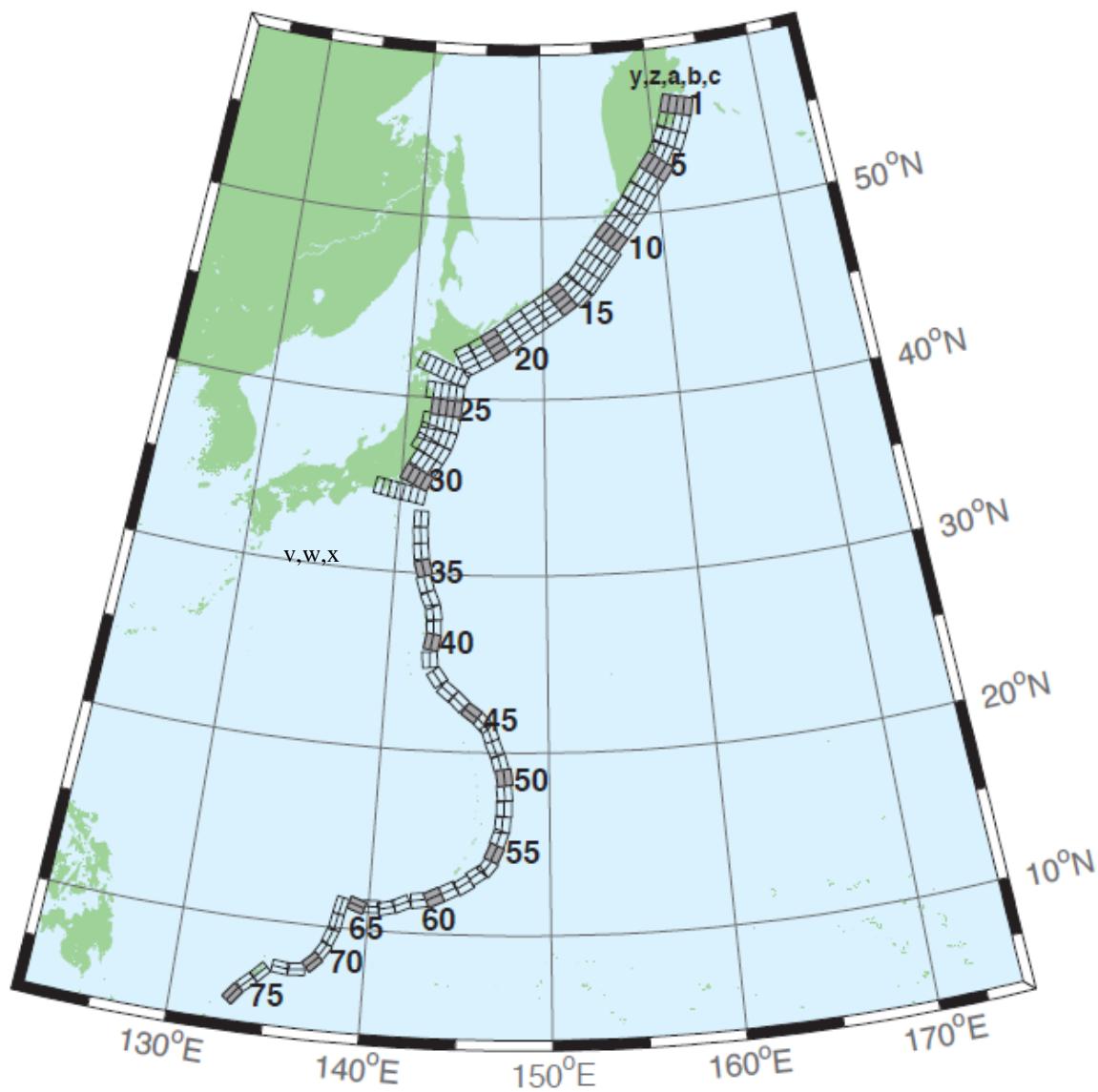


Figure 129. Kamchatka-Kuril-Japan-Izu-Mariana-Yap Subduction Zone unit sources.

Table 10. Earthquake parameters for Kamchatka-Kuril-Japan-Izu-Mariana-Yap Subduction Zone unit sources.

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
kisz-00a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	162.8200	56.3667	29.00	194.41	26.13
kisz-00b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	163.5057	56.2677	25.00	195.00	5.00
kisz-00z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	162.1309	56.4618	29.00	193.84	50.37
kisz-01a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	162.4318	55.5017	29.00	195.00	26.13
kisz-01b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	163.1000	55.4000	25.00	195.00	5.00
kisz-01y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	161.0884	55.7050	29.00	195.00	74.61
kisz-01z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	161.7610	55.6033	29.00	195.00	50.37
kisz-02a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	161.9883	54.6784	29.00	200.00	26.13
kisz-02b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	162.6247	54.5440	25.00	200.00	5.00
kisz-02y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	160.7072	54.9471	29.00	200.00	74.61
kisz-02z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	161.3488	54.8127	29.00	200.00	50.37
kisz-03a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	161.4385	53.8714	29.00	204.00	26.13
kisz-03b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	162.0449	53.7116	25.00	204.00	5.00
kisz-03y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	160.2164	54.1910	29.00	204.00	74.61
kisz-03z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	160.8286	54.0312	29.00	204.00	50.37
kisz-04a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	160.7926	53.1087	29.00	210.00	26.13
kisz-04b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	161.3568	52.9123	25.00	210.00	5.00
kisz-04y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	159.6539	53.5015	29.00	210.00	74.61
kisz-04z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	160.2246	53.3051	29.00	210.00	50.37
kisz-05a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	160.0211	52.4113	29.00	218.00	26.13

Table 10. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
kisz-05b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	160.5258	52.1694	25.00	218.00	5.00
kisz-05y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	159.0005	52.8950	29.00	218.00	74.61
kisz-05z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	159.5122	52.6531	29.00	218.00	50.37
kisz-06a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	159.1272	51.7034	29.00	218.00	26.13
kisz-06b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	159.6241	51.4615	25.00	218.00	5.00
kisz-06y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	158.1228	52.1871	29.00	218.00	74.61
kisz-06z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	158.6263	51.9452	29.00	218.00	50.37
kisz-07a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	158.2625	50.9549	29.00	214.00	26.13
kisz-07b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	158.7771	50.7352	25.00	214.00	5.00
kisz-07y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	157.2236	51.3942	29.00	214.00	74.61
kisz-07z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	157.7443	51.1745	29.00	214.00	50.37
kisz-08a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	157.4712	50.2459	31.00	218.00	27.70
kisz-08b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	157.9433	50.0089	27.00	218.00	5.00
kisz-08y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	156.5176	50.7199	31.00	218.00	79.20
kisz-08z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	156.9956	50.4829	31.00	218.00	53.45
kisz-09a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	156.6114	49.5584	31.00	220.00	27.70
kisz-09b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	157.0638	49.3109	27.00	220.00	5.00
kisz-09y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	155.6974	50.0533	31.00	220.00	79.20
kisz-09z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	156.1556	49.8058	31.00	220.00	53.45
kisz-10a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	155.7294	48.8804	31.00	221.00	27.70
kisz-10b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	156.1690	48.6278	27.00	221.00	5.00

Table 10. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
kisz-10y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	154.8413	49.3856	31.00	221.00	79.20
kisz-10z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	155.2865	49.1330	31.00	221.00	53.45
kisz-11a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	154.8489	48.1821	31.00	219.00	27.70
kisz-11b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	155.2955	47.9398	27.00	219.00	5.00
kisz-11c	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	156.0358	47.5375	57.89	39.00	4.60
kisz-11y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	153.9472	48.6667	31.00	219.00	79.20
kisz-11z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	154.3991	48.4244	31.00	219.00	53.45
kisz-12a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	153.9994	47.4729	31.00	217.00	27.70
kisz-12b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	154.4701	47.2320	27.00	217.00	5.00
kisz-12c	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	155.2207	46.8473	57.89	37.00	4.60
kisz-12y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	153.0856	47.9363	31.00	217.00	79.20
kisz-12z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	153.5435	47.7046	31.00	217.00	53.45
kisz-13a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	153.2239	46.7564	31.00	218.00	27.70
kisz-13b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	153.6648	46.5194	27.00	218.00	5.00
kisz-13c	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	154.3957	46.1258	57.89	38.00	4.60
kisz-13y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	152.3343	47.2304	31.00	218.00	79.20
kisz-13z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	152.7801	46.9934	31.00	218.00	53.45
kisz-14a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	152.3657	46.1515	23.00	225.00	24.54
kisz-14b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	152.7855	45.8591	23.00	225.00	5.00
kisz-14c	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	153.4468	45.3976	57.89	45.00	4.60

Table 10. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
kisz-14y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	151.5172	46.7362	23.00	225.00	63.62
kisz-14z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	151.9426	46.4438	23.00	225.00	44.08
kisz-15a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	151.4663	45.5963	25.00	233.00	23.73
kisz-15b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	151.8144	45.2712	22.00	233.00	5.00
kisz-15y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	150.7619	46.2465	25.00	233.00	65.99
kisz-15z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	151.1151	45.9214	25.00	233.00	44.86
kisz-16a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	150.4572	45.0977	25.00	237.00	23.73
kisz-16b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	150.7694	44.7563	22.00	237.00	5.00
kisz-16y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	149.8253	45.7804	25.00	237.00	65.99
kisz-16z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	150.1422	45.4390	25.00	237.00	44.86
kisz-17a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	149.3989	44.6084	25.00	237.00	23.73
kisz-17b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	149.7085	44.2670	22.00	237.00	5.00
kisz-17y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	148.7723	45.2912	25.00	237.00	65.99
kisz-17z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	149.0865	44.9498	25.00	237.00	44.86
kisz-18a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	148.3454	44.0982	25.00	235.00	23.73
kisz-18b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	148.6687	43.7647	22.00	235.00	5.00
kisz-18y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	147.6915	44.7651	25.00	235.00	65.99
kisz-18z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	148.0194	44.4316	25.00	235.00	44.86
kisz-19a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	147.3262	43.5619	25.00	233.00	23.73
kisz-19b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	147.6625	43.2368	22.00	233.00	5.00
kisz-19y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.6463	44.2121	25.00	233.00	65.99

Table 10. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
kisz-19z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.9872	43.8870	25.00	233.00	44.86
kisz-20a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.3513	43.0633	25.00	237.00	23.73
kisz-20b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.6531	42.7219	22.00	237.00	5.00
kisz-20y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	145.7410	43.7461	25.00	237.00	65.99
kisz-20z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.0470	43.4047	25.00	237.00	44.86
kisz-21a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	145.3331	42.5948	25.00	239.00	23.73
kisz-21b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	145.6163	42.2459	22.00	239.00	5.00
kisz-21y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	144.7603	43.2927	25.00	239.00	65.99
kisz-21z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	145.0475	42.9438	25.00	239.00	44.86
kisz-22a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	144.3041	42.1631	25.00	242.00	23.73
kisz-22b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	144.5605	41.8037	22.00	242.00	5.00
kisz-22y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	143.7854	42.8819	25.00	242.00	65.99
kisz-22z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	144.0455	42.5225	25.00	242.00	44.86
kisz-23a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	143.2863	41.3335	21.00	202.00	21.28
kisz-23b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	143.8028	41.1764	19.00	202.00	5.00
kisz-23v	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	140.6816	42.1189	21.00	202.00	110.87
kisz-23w	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.2050	41.9618	21.00	202.00	92.95
kisz-23x	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.7273	41.8047	21.00	202.00	75.04
kisz-23y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.2482	41.6476	21.00	202.00	57.12
kisz-23z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.7679	41.4905	21.00	202.00	39.20
kisz-24a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.9795	40.3490	21.00	185.00	21.28

Table 10. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
kisz-24b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	143.5273	40.3125	19.00	185.00	5.00
kisz-24x	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.3339	40.4587	21.00	185.00	75.04
kisz-24y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.8827	40.4221	21.00	185.00	57.12
kisz-24z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.4312	40.3856	21.00	185.00	39.20
kisz-25a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.8839	39.4541	21.00	185.00	21.28
kisz-25b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	143.4246	39.4176	19.00	185.00	5.00
kisz-25y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.8012	39.5272	21.00	185.00	57.12
kisz-25z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.3426	39.4907	21.00	185.00	39.20
kisz-26a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.7622	38.5837	21.00	188.00	21.28
kisz-26b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	143.2930	38.5254	19.00	188.00	5.00
kisz-26x	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.1667	38.7588	21.00	188.00	75.04
kisz-26y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.6990	38.7004	21.00	188.00	57.12
kisz-26z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.2308	38.6421	21.00	188.00	39.20
kisz-27a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.5320	37.7830	21.00	198.00	21.28
kisz-27b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	143.0357	37.6534	19.00	198.00	5.00
kisz-27x	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.0142	38.1717	21.00	198.00	75.04
kisz-27y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.5210	38.0421	21.00	198.00	57.12
kisz-27z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.0269	37.9126	21.00	198.00	39.20
kisz-28a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.1315	37.0265	21.00	208.00	21.28
kisz-28b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.5941	36.8297	19.00	208.00	5.00
kisz-28x	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	140.7348	37.6171	21.00	208.00	75.04

Table 10. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
kisz-28y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.2016	37.4202	21.00	208.00	57.12
kisz-28z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.6671	37.2234	21.00	208.00	39.20
kisz-29a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.5970	36.2640	21.00	211.00	21.28
kisz-29b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.0416	36.0481	19.00	211.00	5.00
kisz-29y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	140.7029	36.6960	21.00	211.00	57.12
kisz-29z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.1506	36.4800	21.00	211.00	39.20
kisz-30a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.0553	35.4332	21.00	205.00	21.28
kisz-30b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.5207	35.2560	19.00	205.00	5.00
kisz-30y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	140.1204	35.7876	21.00	205.00	57.12
kisz-30z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	140.5883	35.6104	21.00	205.00	39.20
kisz-31a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	140.6956	34.4789	22.00	190.00	22.10
kisz-31b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.1927	34.4066	20.00	190.00	5.00
kisz-31v	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	138.2025	34.8405	22.00	190.00	115.75
kisz-31w	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	138.7021	34.7682	22.00	190.00	97.02
kisz-31x	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	139.2012	34.6958	22.00	190.00	78.29
kisz-31y	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	139.6997	34.6235	22.00	190.00	59.56
kisz-31z	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	140.1979	34.5512	22.00	190.00	40.83
kisz-32a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.0551	33.0921	32.00	180.00	23.48
kisz-32b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.5098	33.0921	21.69	180.00	5.00
kisz-33a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.0924	32.1047	27.65	173.85	20.67
kisz-33b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.5596	32.1473	18.27	173.85	5.00

Table 10. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
kisz-34a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.1869	31.1851	25.00	172.14	18.26
kisz-34b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.6585	31.2408	15.38	172.14	5.00
kisz-35a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.4154	30.1707	25.00	162.98	17.12
kisz-35b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.8662	30.2899	14.03	162.98	5.00
kisz-36a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.6261	29.2740	25.73	161.68	18.71
kisz-36b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.0670	29.4012	15.91	161.68	5.00
kisz-37a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.0120	28.3322	20.00	154.72	14.54
kisz-37b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.4463	28.5124	11.00	154.72	5.00
kisz-38a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.2254	27.6946	20.00	170.27	14.54
kisz-38b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.6955	27.7659	11.00	170.27	5.00
kisz-39a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.3085	26.9127	24.23	177.23	17.42
kisz-39b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.7674	26.9325	14.38	177.23	5.00
kisz-40a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.2673	26.1923	26.49	189.44	22.26
kisz-40b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.7090	26.1264	20.20	189.44	5.00
kisz-41a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.1595	25.0729	22.07	173.72	19.08
kisz-41b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.6165	25.1184	16.36	173.72	5.00
kisz-42a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.7641	23.8947	21.54	143.50	18.40
kisz-42b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	143.1321	24.1432	15.54	143.50	5.00
kisz-43a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	143.5281	23.0423	23.02	129.21	18.77
kisz-43b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	143.8128	23.3626	15.99	129.21	5.00
kisz-44a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	144.2230	22.5240	28.24	134.63	18.56

Table 10. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
kisz-44b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	144.5246	22.8056	15.74	134.63	5.00
kisz-45a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	145.0895	21.8866	36.73	125.83	22.79
kisz-45b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	145.3171	22.1785	20.84	125.83	5.00
kisz-46a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	145.6972	21.3783	30.75	135.90	20.63
kisz-46b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	145.9954	21.6469	18.22	135.90	5.00
kisz-47a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.0406	20.9341	29.87	160.07	19.62
kisz-47b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.4330	21.0669	17.00	160.07	5.00
kisz-48a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.3836	20.0690	32.75	157.96	19.68
kisz-48b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.7567	20.2108	17.07	157.96	5.00
kisz-49a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.6689	19.3123	25.07	164.48	21.41
kisz-49b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	147.0846	19.4212	19.16	164.48	5.00
kisz-50a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.9297	18.5663	22.00	172.07	22.10
kisz-50b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	147.3650	18.6238	20.00	172.07	5.00
kisz-51a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.9495	17.7148	22.06	175.11	22.04
kisz-51b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	147.3850	17.7503	19.93	175.11	5.00
kisz-52a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.9447	16.8869	25.51	180.00	18.61
kisz-52b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	147.3683	16.8869	15.79	180.00	5.00
kisz-53a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.8626	16.0669	27.39	185.18	18.41
kisz-53b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	147.2758	16.0309	15.56	185.18	5.00
kisz-54a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.7068	15.3883	28.12	199.05	20.91
kisz-54b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	147.0949	15.2590	18.56	199.05	5.00

Table 10. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
kisz-55a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.4717	14.6025	29.60	204.35	26.27
kisz-55b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.8391	14.4415	25.18	204.35	5.00
kisz-56a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.1678	13.9485	32.04	217.45	26.79
kisz-56b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	146.4789	13.7170	25.84	217.45	5.00
kisz-57a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	145.6515	13.5576	37.00	235.81	24.54
kisz-57b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	145.8586	13.2609	23.00	235.81	5.00
kisz-58a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	144.9648	12.9990	37.72	237.80	24.54
kisz-58b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	145.1589	12.6984	23.00	237.80	5.00
kisz-59a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	144.1799	12.6914	34.33	242.87	22.31
kisz-59b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	144.3531	12.3613	20.25	242.87	5.00
kisz-60a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	143.3687	12.3280	30.90	244.95	20.62
kisz-60b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	143.5355	11.9788	18.20	244.95	5.00
kisz-61a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.7051	12.1507	35.41	261.84	25.51
kisz-61b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	142.7582	11.7883	24.22	261.84	5.00
kisz-62a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.6301	11.8447	39.86	245.69	34.35
kisz-62b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	141.7750	11.5305	35.94	245.69	5.00
kisz-63a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	140.8923	11.5740	42.00	256.20	38.46
kisz-63b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	140.9735	11.2498	42.00	256.20	5.00
kisz-64a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	140.1387	11.6028	42.48	269.61	38.77
kisz-64b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	140.1410	11.2716	42.48	269.61	5.00
kisz-65a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	139.4595	11.5883	44.16	288.71	39.83

Table 10. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
kisz-65b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	139.3541	11.2831	44.16	288.71	5.00
kisz-66a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	138.1823	11.2648	45.00	193.08	40.36
kisz-66b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	138.4977	11.1929	45.00	193.08	5.00
kisz-67a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	137.9923	10.3398	45.00	189.83	40.36
kisz-67b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	138.3104	10.2856	45.00	189.83	5.00
kisz-68a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	137.7607	9.6136	45.00	201.68	40.36
kisz-68b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	138.0599	9.4963	45.00	201.68	5.00
kisz-69a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	137.4537	8.8996	45.00	213.54	40.36
kisz-69b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	137.7215	8.7241	45.00	213.54	5.00
kisz-70a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	137.0191	8.2872	45.00	226.47	40.36
kisz-70b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	137.2400	8.0569	45.00	226.47	5.00
kisz-71a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	136.3863	7.9078	45.00	263.92	40.36
kisz-71b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	136.4202	7.5920	45.00	263.92	5.00
kisz-72a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	135.6310	7.9130	45.00	276.87	40.36
kisz-72b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	135.5926	7.5977	45.00	276.87	5.00
kisz-73a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	134.3296	7.4541	45.00	223.98	40.36
kisz-73b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	134.5600	7.2335	45.00	223.98	5.00
kisz-74a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	133.7125	6.8621	45.00	228.06	40.36
kisz-74b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	133.9263	6.6258	45.00	228.06	5.00
kisz-75a	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	133.0224	6.1221	45.00	217.68	40.36
kisz-75b	Kamchatka-Kuril-Japan-Izu-Mariana-Yap	133.2751	5.9280	45.00	217.68	5.00

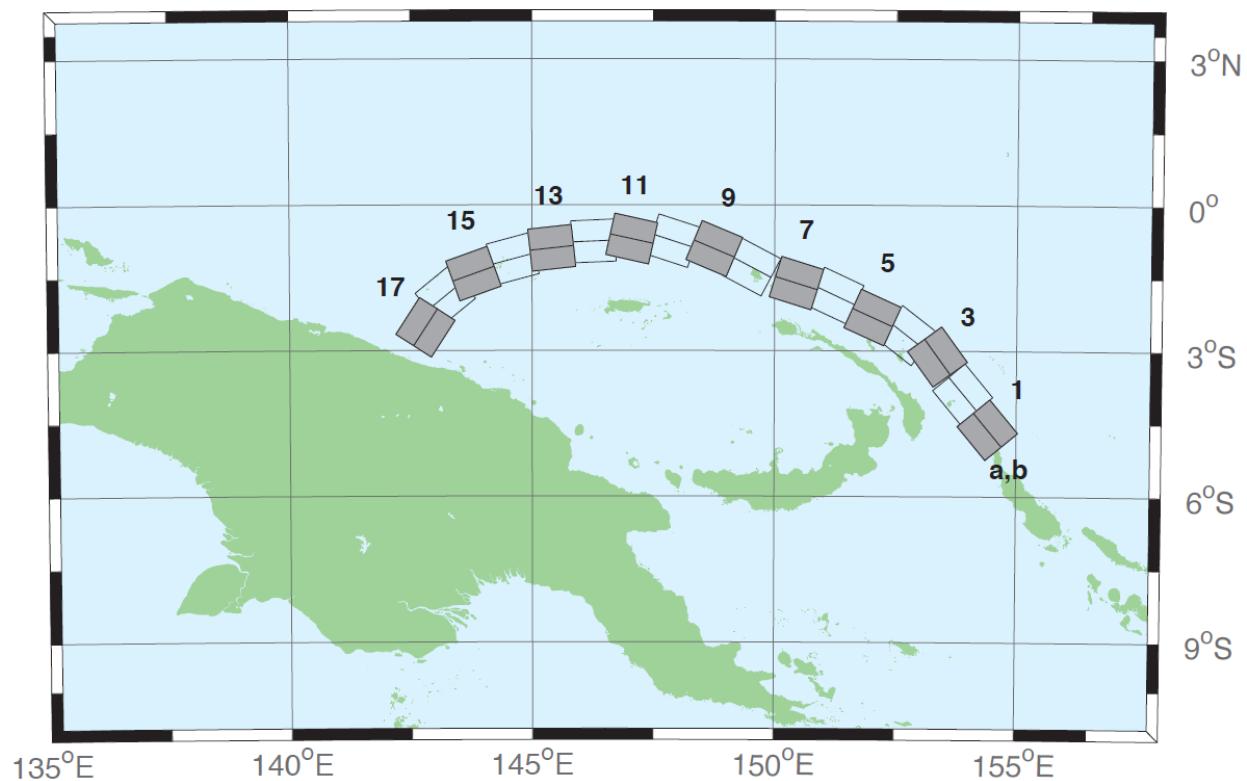


Figure 130. Manus Oceanic Convergent Boundary Subduction Zone unit sources.

Table 11. Earthquake parameters for Manus Oceanic Convergent Boundary Subduction Zone unit sources.

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
mosz-01a	Manus	154.0737	-4.8960	15.00	140.23	15.88
mosz-01b	Manus	154.4082	-4.6185	15.00	140.23	2.94
mosz-02a	Manus	153.5589	-4.1575	15.00	140.23	15.91
mosz-02b	Manus	153.8931	-3.8800	15.00	140.23	2.97
mosz-03a	Manus	153.0151	-3.3716	15.00	143.91	16.64
mosz-03b	Manus	153.3662	-3.1160	15.00	143.91	3.70
mosz-04a	Manus	152.4667	-3.0241	15.00	127.66	17.32
mosz-04b	Manus	152.7321	-2.6806	15.00	127.66	4.38
mosz-05a	Manus	151.8447	-2.7066	15.00	114.32	17.57
mosz-05b	Manus	152.0235	-2.3112	15.00	114.32	4.63
mosz-06a	Manus	151.0679	-2.2550	15.00	114.99	17.66
mosz-06b	Manus	151.2513	-1.8618	15.00	114.99	4.72
mosz-07a	Manus	150.3210	-2.0236	15.00	107.20	17.73
mosz-07b	Manus	150.4493	-1.6092	15.00	107.20	4.79
mosz-08a	Manus	149.3226	-1.6666	15.00	117.82	17.83
mosz-08b	Manus	149.5251	-1.2829	15.00	117.82	4.89
mosz-09a	Manus	148.5865	-1.3017	15.00	112.71	17.84
mosz-09b	Manus	148.7540	-0.9015	15.00	112.71	4.90
mosz-10a	Manus	147.7760	-1.1560	15.00	108.01	17.78
mosz-10b	Manus	147.9102	-0.7434	15.00	108.01	4.84
mosz-11a	Manus	146.9596	-1.1226	15.00	102.45	17.54
mosz-11b	Manus	147.0531	-0.6990	15.00	102.45	4.60
mosz-12a	Manus	146.2858	-1.1820	15.00	87.48	17.29
mosz-12b	Manus	146.2667	-0.7486	15.00	87.48	4.35
mosz-13a	Manus	145.4540	-1.3214	15.00	83.75	17.34
mosz-13b	Manus	145.4068	-0.8901	15.00	83.75	4.40
mosz-14a	Manus	144.7151	-1.5346	15.00	75.09	17.21
mosz-14b	Manus	144.6035	-1.1154	15.00	75.09	4.27
mosz-15b	Manus	143.7940	-1.4190	15.00	70.43	3.58
mosz-16a	Manus	143.4850	-2.2118	15.00	50.79	15.86
mosz-16b	Manus	143.2106	-1.8756	15.00	50.79	2.92
mosz-17a	Manus	143.1655	-2.7580	15.00	33.00	16.64
mosz-17b	Manus	142.8013	-2.5217	15.00	33.00	3.70

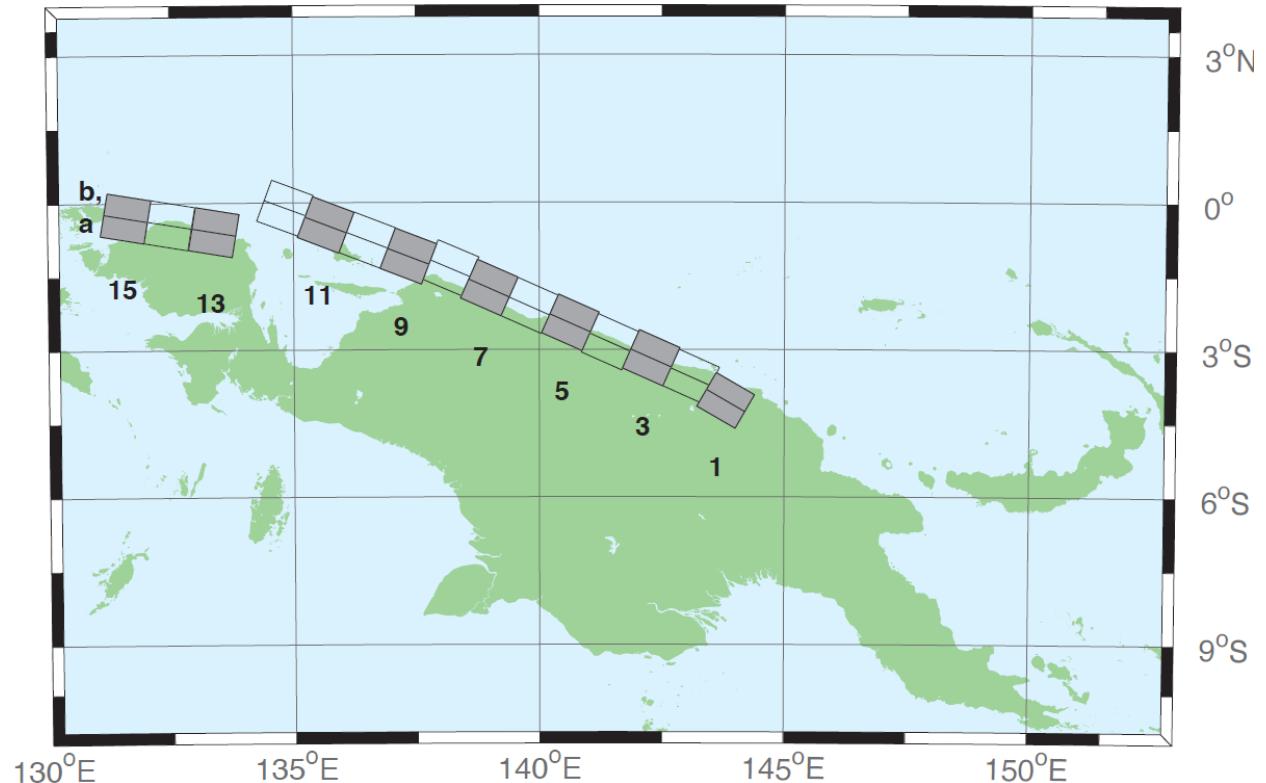


Figure 131. New Guinea Subduction Zone unit sources.

Table 12. Earthquake parameters for Manus Oceanic Convergent Boundary Subduction Zone unit sources.

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
ngsz-01a	New Guinea	143.6063	-4.3804	29.00	120.00	25.64
ngsz-01b	New Guinea	143.8032	-4.0402	29.00	120.00	1.40
ngsz-02a	New Guinea	142.9310	-3.9263	27.63	114.00	20.10
ngsz-02b	New Guinea	143.0932	-3.5628	21.72	114.00	1.60
ngsz-03a	New Guinea	142.1076	-3.5632	20.06	114.00	18.73
ngsz-03b	New Guinea	142.2795	-3.1778	15.94	114.00	5.00
ngsz-04a	New Guinea	141.2681	-3.2376	21.00	114.00	17.76
ngsz-04b	New Guinea	141.4389	-2.8545	14.79	114.00	5.00
ngsz-05a	New Guinea	140.4592	-2.8429	21.26	114.00	16.14
ngsz-05b	New Guinea	140.6296	-2.4605	12.87	114.00	5.00
ngsz-06a	New Guinea	139.6288	-2.4960	22.72	114.00	15.40
ngsz-06b	New Guinea	139.7974	-2.1175	12.00	114.00	5.00
ngsz-07a	New Guinea	138.8074	-2.1312	21.39	114.00	15.40
ngsz-07b	New Guinea	138.9776	-1.7491	12.00	114.00	5.00
ngsz-08a	New Guinea	138.0185	-1.7353	18.79	113.09	15.14
ngsz-08b	New Guinea	138.1853	-1.3441	11.70	113.09	5.00
ngsz-09a	New Guinea	137.1805	-1.5037	15.24	111.00	13.23
ngsz-09b	New Guinea	137.3358	-1.0991	9.47	111.00	5.00
ngsz-10a	New Guinea	136.3418	-1.1774	13.51	111.00	11.09
ngsz-10b	New Guinea	136.4983	-0.7697	7.00	111.00	5.00
ngsz-11a	New Guinea	135.4984	-0.8641	11.38	111.00	12.49
ngsz-11b	New Guinea	135.6562	-0.4530	8.62	111.00	5.00
ngsz-12a	New Guinea	134.6759	-0.5216	10.00	110.48	13.68
ngsz-12b	New Guinea	134.8307	-0.1072	10.00	110.48	5.00
ngsz-13a	New Guinea	133.3065	-1.0298	10.00	99.50	13.68
ngsz-13b	New Guinea	133.3795	-0.5935	10.00	99.50	5.00
ngsz-14a	New Guinea	132.4048	-0.8816	10.00	99.50	13.68
ngsz-14b	New Guinea	132.4778	-0.4453	10.00	99.50	5.00
ngsz-15a	New Guinea	131.5141	-0.7353	10.00	99.50	13.68
ngsz-15b	New Guinea	131.5871	-0.2990	10.00	99.50	5.00

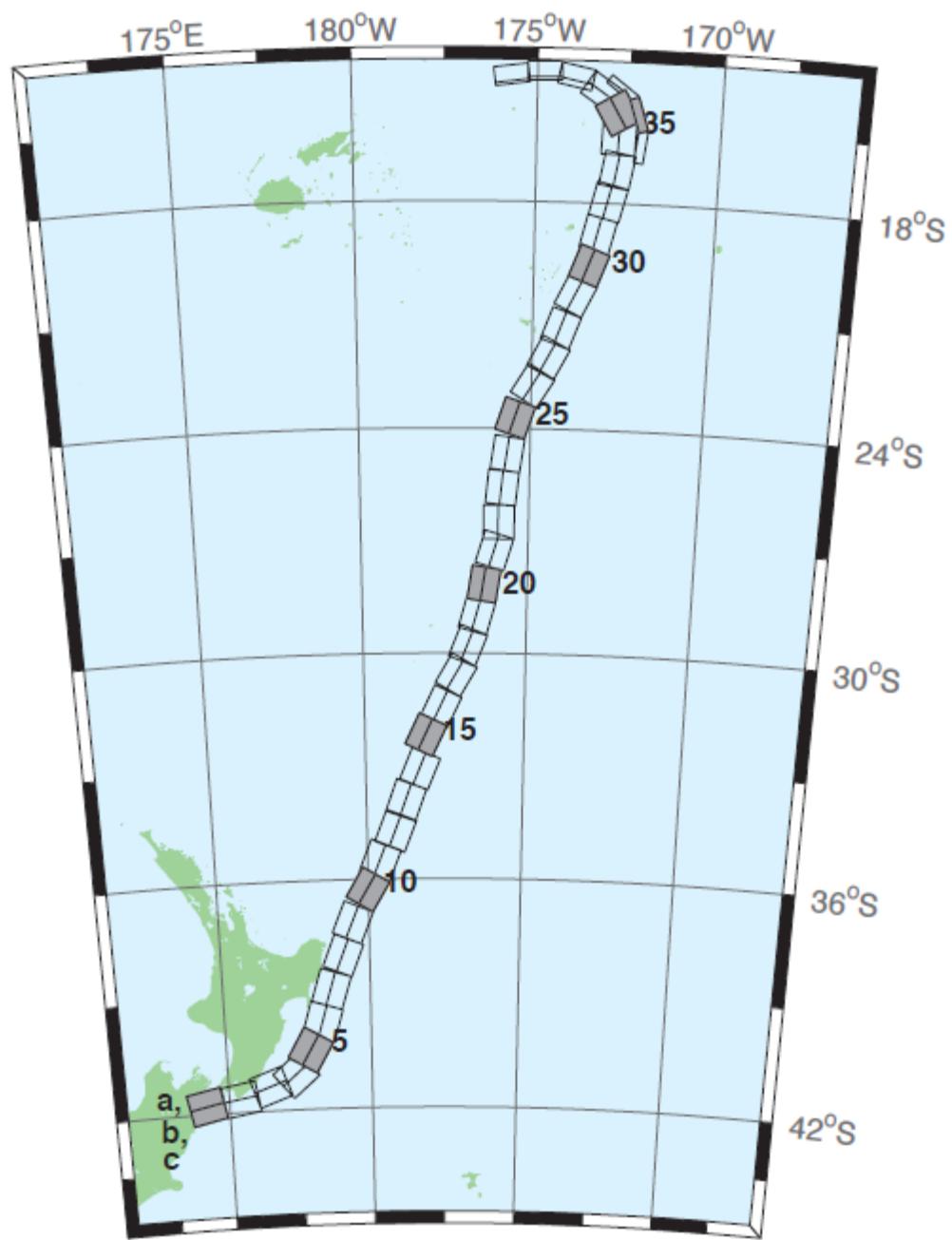


Figure 132. New Zealand-Kermadec-Tonga Subduction Zone unit sources.

Table 13. Earthquake parameters for New Zealand-Kermadec-Tonga Subduction Zone unit sources.

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
ntsз-01a	New Zealand-Tonga	174.0985	-41.3951	24.00	258.57	25.34
ntsз-01b	New Zealand-Tonga	174.2076	-41.7973	24.00	258.57	5.00
ntsз-02a	New Zealand-Tonga	175.3289	-41.2592	29.38	260.63	23.17
ntsз-02b	New Zealand-Tonga	175.4142	-41.6454	21.31	260.63	5.00
ntsз-03a	New Zealand-Tonga	176.2855	-40.9950	29.54	250.65	21.74
ntsз-03b	New Zealand-Tonga	176.4580	-41.3637	19.56	250.65	5.00
ntsз-04a	New Zealand-Tonga	177.0023	-40.7679	24.43	229.42	18.87
ntsз-04b	New Zealand-Tonga	177.3552	-41.0785	16.10	229.42	5.00
ntsз-05a	New Zealand-Tonga	177.4114	-40.2396	18.80	210.04	19.29
ntsз-05b	New Zealand-Tonga	177.8951	-40.4525	16.61	210.04	5.00
ntsз-06a	New Zealand-Tonga	177.8036	-39.6085	18.17	196.68	15.80
ntsз-06b	New Zealand-Tonga	178.3352	-39.7310	12.48	196.68	5.00
ntsз-07a	New Zealand-Tonga	178.1676	-38.7480	28.10	197.03	17.85
ntsз-07b	New Zealand-Tonga	178.6541	-38.8640	14.89	197.03	5.00
ntsз-08a	New Zealand-Tonga	178.6263	-37.8501	31.47	201.41	18.78
ntsз-08b	New Zealand-Tonga	179.0788	-37.9899	16.00	201.41	5.00
ntsз-09a	New Zealand-Tonga	178.9833	-36.9770	29.58	202.19	20.02
ntsз-09b	New Zealand-Tonga	179.4369	-37.1245	17.48	202.19	5.00
ntsз-10a	New Zealand-Tonga	179.5534	-36.0655	32.10	210.62	20.72
ntsз-10b	New Zealand-Tonga	179.9595	-36.2593	18.32	210.62	5.00
ntsз-11a	New Zealand-Tonga	179.9267	-35.3538	25.00	201.65	16.09
ntsз-11b	New Zealand-Tonga	180.3915	-35.5040	12.81	201.65	5.00
ntsз-12a	New Zealand-Tonga	180.4433	-34.5759	25.00	201.18	15.46
ntsз-12b	New Zealand-Tonga	180.9051	-34.7230	12.08	201.18	5.00
ntsз-13a	New Zealand-Tonga	180.7990	-33.7707	25.87	199.75	19.06
ntsз-13b	New Zealand-Tonga	181.2573	-33.9073	16.33	199.75	5.00
ntsз-14a	New Zealand-Tonga	181.2828	-32.9288	31.28	202.41	22.73
ntsз-14b	New Zealand-Tonga	181.7063	-33.0751	20.77	202.41	5.00
ntsз-15a	New Zealand-Tonga	181.4918	-32.0035	32.33	205.43	22.64
ntsз-15b	New Zealand-Tonga	181.8967	-32.1665	20.66	205.43	5.00
ntsз-16a	New Zealand-Tonga	181.9781	-31.2535	34.29	205.48	23.59
ntsз-16b	New Zealand-Tonga	182.3706	-31.4131	21.83	205.48	5.00
ntsз-17a	New Zealand-Tonga	182.4819	-30.3859	37.60	210.31	25.58
ntsз-17b	New Zealand-Tonga	182.8387	-30.5655	24.30	210.31	5.00
ntsз-18a	New Zealand-Tonga	182.8176	-29.6545	37.65	201.63	26.13
ntsз-18b	New Zealand-Tonga	183.1985	-29.7856	25.00	201.63	5.00

Table 13. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
ntsz-19a	New Zealand-Tonga	183.0622	-28.8739	34.41	195.70	26.13
ntsz-19b	New Zealand-Tonga	183.4700	-28.9742	25.00	195.70	5.00
ntsz-20a	New Zealand-Tonga	183.2724	-28.0967	38.00	188.80	26.13
ntsz-20b	New Zealand-Tonga	183.6691	-28.1508	25.00	188.80	5.00
ntsz-21a	New Zealand-Tonga	183.5747	-27.1402	32.29	197.10	24.83
ntsz-21b	New Zealand-Tonga	183.9829	-27.2518	23.37	197.10	5.00
ntsz-22a	New Zealand-Tonga	183.6608	-26.4975	29.56	180.00	18.63
ntsz-22b	New Zealand-Tonga	184.0974	-26.4975	15.82	180.00	5.00
ntsz-23a	New Zealand-Tonga	183.7599	-25.5371	32.42	185.77	20.56
ntsz-23b	New Zealand-Tonga	184.1781	-25.5752	18.13	185.77	5.00
ntsz-24a	New Zealand-Tonga	183.9139	-24.6201	33.31	188.17	23.73
ntsz-24b	New Zealand-Tonga	184.3228	-24.6734	22.00	188.17	5.00
ntsz-25a	New Zealand-Tonga	184.1266	-23.5922	29.34	198.48	19.64
ntsz-25b	New Zealand-Tonga	184.5322	-23.7163	17.03	198.48	5.00
ntsz-26a	New Zealand-Tonga	184.6613	-22.6460	30.26	211.67	19.43
ntsz-26b	New Zealand-Tonga	185.0196	-22.8497	16.78	211.67	5.00
ntsz-27a	New Zealand-Tonga	185.0879	-21.9139	31.73	207.93	20.67
ntsz-27b	New Zealand-Tonga	185.4522	-22.0928	18.27	207.93	5.00
ntsz-28a	New Zealand-Tonga	185.4037	-21.1758	32.44	200.48	21.76
ntsz-28b	New Zealand-Tonga	185.7849	-21.3084	19.58	200.48	5.00
ntsz-29a	New Zealand-Tonga	185.8087	-20.2629	32.47	206.37	20.40
ntsz-29b	New Zealand-Tonga	186.1710	-20.4312	17.94	206.37	5.00
ntsz-30a	New Zealand-Tonga	186.1499	-19.5087	32.98	200.91	22.46
ntsz-30b	New Zealand-Tonga	186.5236	-19.6432	20.44	200.91	5.00
ntsz-31a	New Zealand-Tonga	186.3538	-18.7332	34.41	193.88	21.19
ntsz-31b	New Zealand-Tonga	186.7339	-18.8221	18.89	193.88	5.00
ntsz-32a	New Zealand-Tonga	186.5949	-17.8587	30.00	194.12	19.12
ntsz-32b	New Zealand-Tonga	186.9914	-17.9536	16.40	194.12	5.00
ntsz-33a	New Zealand-Tonga	186.8172	-17.0581	33.15	190.04	23.34
ntsz-33b	New Zealand-Tonga	187.2047	-17.1237	21.52	190.04	5.00
ntsz-34a	New Zealand-Tonga	186.7814	-16.2598	15.00	182.13	13.41
ntsz-34b	New Zealand-Tonga	187.2330	-16.2759	9.68	182.13	5.00
ntsz-34c*	New Zealand-Tonga	187.9697	-16.4956	57.06	7.62	6.57
ntsz-35a	New Zealand-Tonga	186.8000	-15.8563	15.00	149.85	12.17
ntsz-35b	New Zealand-Tonga	187.1896	-15.6384	8.24	149.85	5.00

Table 13. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
ntsz-35c*	New Zealand-Tonga	187.8775	-15.6325	57.06	342.45	6.57
ntsz-36a	New Zealand-Tonga	186.5406	-15.3862	40.44	123.91	36.72
ntsz-36b	New Zealand-Tonga	186.7381	-15.1025	39.38	123.91	5.00
ntsz-36c*	New Zealand-Tonga	187.3791	-14.9234	57.06	307.04	6.57
ntsz-37a	New Zealand-Tonga	185.9883	-14.9861	68.94	101.95	30.99
ntsz-37b	New Zealand-Tonga	186.0229	-14.8282	31.32	101.95	5.00
ntsz-38a	New Zealand-Tonga	185.2067	-14.8259	80.00	88.40	26.13
ntsz-38b	New Zealand-Tonga	185.2044	-14.7479	25.00	88.40	5.00
ntsz-39a	New Zealand-Tonga	184.3412	-14.9409	80.00	82.55	26.13
ntsz-39b	New Zealand-Tonga	184.3307	-14.8636	25.00	82.55	5.00

\*Rake angle is -90°

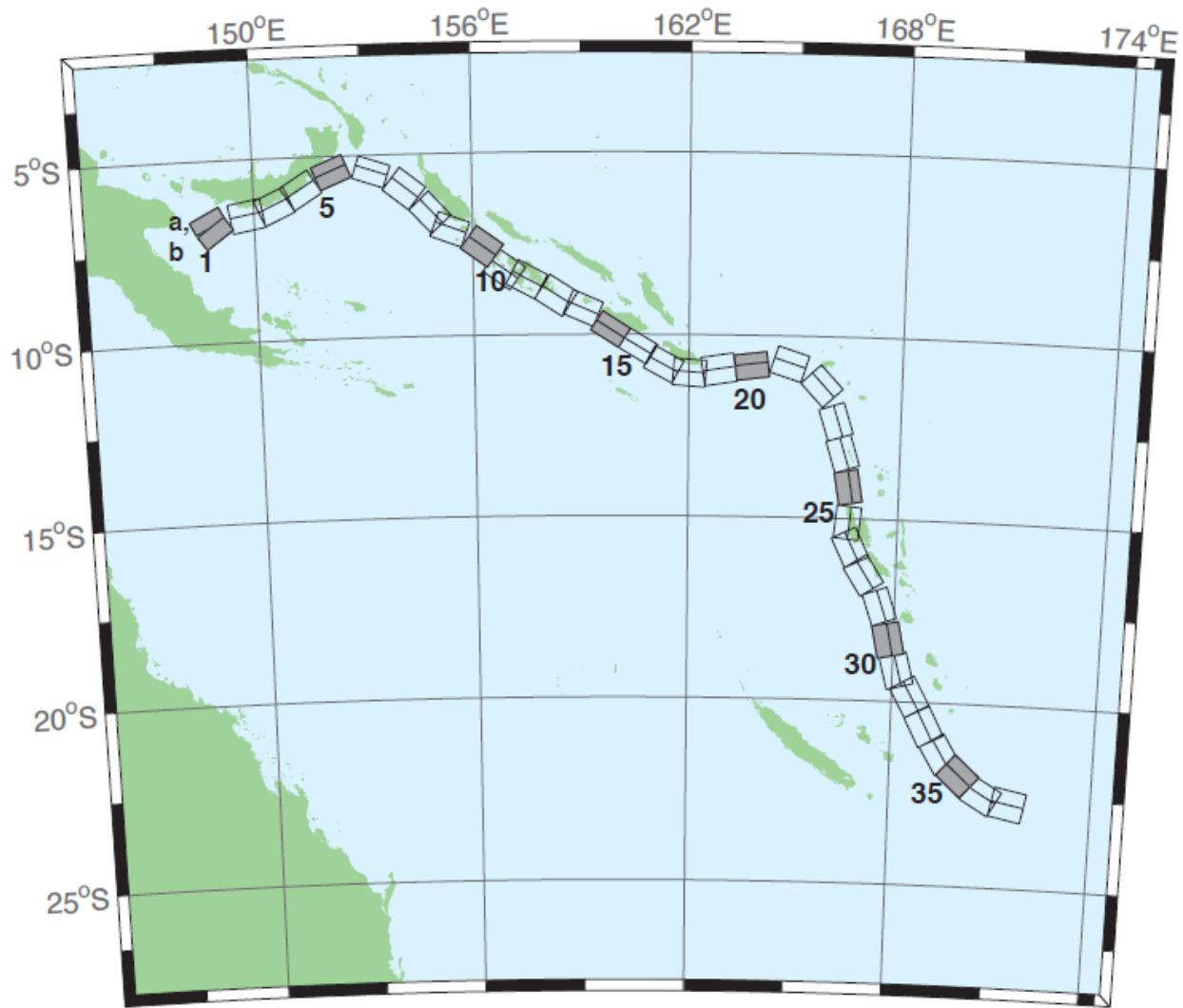


Figure 133. New Britain-Solomons-Vanuatu Zone unit sources.

Table 14. Earthquake parameters for New Zealand-Kermadec-Tonga Subduction Zone unit sources.

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
nvsz-01a	New Britain-Vanuatu	148.6217	-6.4616	32.34	243.15	15.69
nvsz-01b	New Britain-Vanuatu	148.7943	-6.8002	12.34	234.15	5.00
nvsz-02a	New Britain-Vanuatu	149.7218	-6.1459	35.10	260.06	16.36
nvsz-02b	New Britain-Vanuatu	149.7856	-6.5079	13.13	260.06	5.00
nvsz-03a	New Britain-Vanuatu	150.4075	-5.9659	42.35	245.69	18.59
nvsz-03b	New Britain-Vanuatu	150.5450	-6.2684	15.77	245.69	5.00
nvsz-04a	New Britain-Vanuatu	151.1095	-5.5820	42.41	238.22	23.63
nvsz-04b	New Britain-Vanuatu	151.2851	-5.8639	21.88	238.22	5.00
nvsz-05a	New Britain-Vanuatu	152.0205	-5.1305	49.22	247.73	32.39
nvsz-05b	New Britain-Vanuatu	152.1322	-5.4020	33.22	247.73	5.00
nvsz-06a	New Britain-Vanuatu	153.3450	-5.1558	53.53	288.58	33.59
nvsz-06b	New Britain-Vanuatu	153.2595	-5.4089	34.87	288.58	5.00
nvsz-07a	New Britain-Vanuatu	154.3814	-5.6308	39.72	308.27	19.18
nvsz-07b	New Britain-Vanuatu	154.1658	-5.9017	16.48	308.27	5.00
nvsz-08a	New Britain-Vanuatu	155.1097	-6.3511	45.33	317.22	22.92
nvsz-08b	New Britain-Vanuatu	154.8764	-6.5656	21.00	317.22	5.00
nvsz-09a	New Britain-Vanuatu	155.5027	-6.7430	48.75	290.51	22.92
nvsz-09b	New Britain-Vanuatu	155.3981	-7.0204	21.00	290.51	5.00
nvsz-10a	New Britain-Vanuatu	156.4742	-7.2515	36.88	305.85	27.62
nvsz-10b	New Britain-Vanuatu	156.2619	-7.5427	26.90	305.85	5.00
nvsz-11a	New Britain-Vanuatu	157.0830	-7.8830	32.97	305.36	29.72
nvsz-11b	New Britain-Vanuatu	156.8627	-8.1903	29.63	305.36	5.00
nvsz-12a	New Britain-Vanuatu	157.6537	-8.1483	37.53	297.94	28.57
nvsz-12b	New Britain-Vanuatu	157.4850	-8.4630	28.13	297.94	5.00
nvsz-13a	New Britain-Vanuatu	158.5089	-8.5953	33.62	302.73	23.02
nvsz-13b	New Britain-Vanuatu	158.3042	-8.9099	21.12	302.73	5.00
nvsz-14a	New Britain-Vanuatu	159.1872	-8.9516	38.44	293.32	34.06
nvsz-14b	New Britain-Vanuatu	159.0461	-9.2747	35.54	293.32	5.00
nvsz-15a	New Britain-Vanuatu	159.9736	-9.5993	46.69	302.76	41.38
nvsz-15b	New Britain-Vanuatu	159.8044	-9.8584	46.69	302.76	5.00
nvsz-16a	New Britain-Vanuatu	160.7343	-10.0574	46.05	300.99	41.00
nvsz-16b	New Britain-Vanuatu	160.5712	-10.3246	46.05	300.99	5.00
nvsz-17a	New Britain-Vanuatu	161.4562	-10.5241	40.12	298.37	37.22
nvsz-17b	New Britain-Vanuatu	161.2900	-10.8263	40.12	298.37	5.00
nvsz-18a	New Britain-Vanuatu	162.0467	-10.6823	40.33	274.07	29.03
nvsz-18b	New Britain-Vanuatu	162.0219	-11.0238	28.72	274.07	5.00
nvsz-19a	New Britain-Vanuatu	162.7818	-10.5645	34.25	261.27	24.14

Table 14. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
nvsz-19b	New Britain-Vanuatu	162.8392	-10.9315	22.51	261.27	5.00
nvsz-20a	New Britain-Vanuatu	163.7222	-10.5014	50.35	262.93	26.30
nvsz-20b	New Britain-Vanuatu	163.7581	-10.7858	25.22	262.93	5.00
nvsz-21a	New Britain-Vanuatu	164.9445	-10.4183	40.31	287.89	23.30
nvsz-21b	New Britain-Vanuatu	164.8374	-10.7442	21.47	287.89	5.00
nvsz-22a	New Britain-Vanuatu	166.0261	-11.1069	42.39	317.08	20.78
nvsz-22b	New Britain-Vanuatu	165.7783	-11.3328	18.40	317.08	5.00
nvsz-23a	New Britain-Vanuatu	166.5179	-12.2260	47.95	342.37	22.43
nvsz-23b	New Britain-Vanuatu	166.2244	-12.3171	20.40	342.37	5.00
nvsz-24a	New Britain-Vanuatu	166.7236	-13.1065	47.13	342.6	28.52
nvsz-24b	New Britain-Vanuatu	166.4241	-13.1979	28.06	342.6	5.00
nvsz-25a	New Britain-Vanuatu	166.8914	-14.0785	54.10	350.28	31.16
nvsz-25b	New Britain-Vanuatu	166.6237	-14.1230	31.55	350.28	5.00
nvsz-26a	New Britain-Vanuatu	166.9200	-15.1450	50.46	365.62	29.05
nvsz-26b	New Britain-Vanuatu	166.6252	-15.1170	28.75	365.62	5.00
nvsz-27a	New Britain-Vanuatu	167.0053	-15.6308	44.74	334.23	25.46
nvsz-27b	New Britain-Vanuatu	166.7068	-15.7695	24.15	334.23	5.00
nvsz-28a	New Britain-Vanuatu	167.4074	-16.3455	41.53	327.46	22.44
nvsz-28b	New Britain-Vanuatu	167.1117	-16.5264	20.42	327.46	5.00
nvsz-29a	New Britain-Vanuatu	167.9145	-17.2807	49.10	341.16	24.12
nvsz-29b	New Britain-Vanuatu	167.6229	-17.3757	22.48	341.16	5.00
nvsz-30a	New Britain-Vanuatu	168.2220	-18.2353	44.19	348.58	23.99
nvsz-30b	New Britain-Vanuatu	167.8895	-18.2991	22.32	348.58	5.00
nvsz-31a	New Britain-Vanuatu	168.5022	-19.0510	42.20	345.59	22.26
nvsz-31b	New Britain-Vanuatu	168.1611	-19.1338	20.20	345.59	5.00
nvsz-32a	New Britain-Vanuatu	168.8775	-19.6724	42.03	331.06	21.68
nvsz-32b	New Britain-Vanuatu	168.5671	-19.8338	19.49	331.06	5.00
nvsz-33a	New Britain-Vanuatu	169.3422	-20.4892	40.25	332.91	22.40
nvsz-33b	New Britain-Vanuatu	169.0161	-20.6453	20.37	332.91	5.00
nvsz-34a	New Britain-Vanuatu	169.8304	-21.2121	39.00	329.15	22.73
nvsz-34b	New Britain-Vanuatu	169.5086	-21.3911	20.77	329.15	5.00
nvsz-35a	New Britain-Vanuatu	170.3119	-21.6945	39.00	311.89	22.13
nvsz-35b	New Britain-Vanuatu	170.0606	-21.9543	20.03	311.89	5.00
nvsz-36a	New Britain-Vanuatu	170.9487	-22.1585	39.42	300.43	23.50
nvsz-36b	New Britain-Vanuatu	170.7585	-22.4577	21.71	300.43	5.00
nvsz-37a	New Britain-Vanuatu	171.6335	-22.3087	30.00	281.26	22.10
nvsz-37b	New Britain-Vanuatu	171.5512	-22.6902	20.00	281.26	5.00

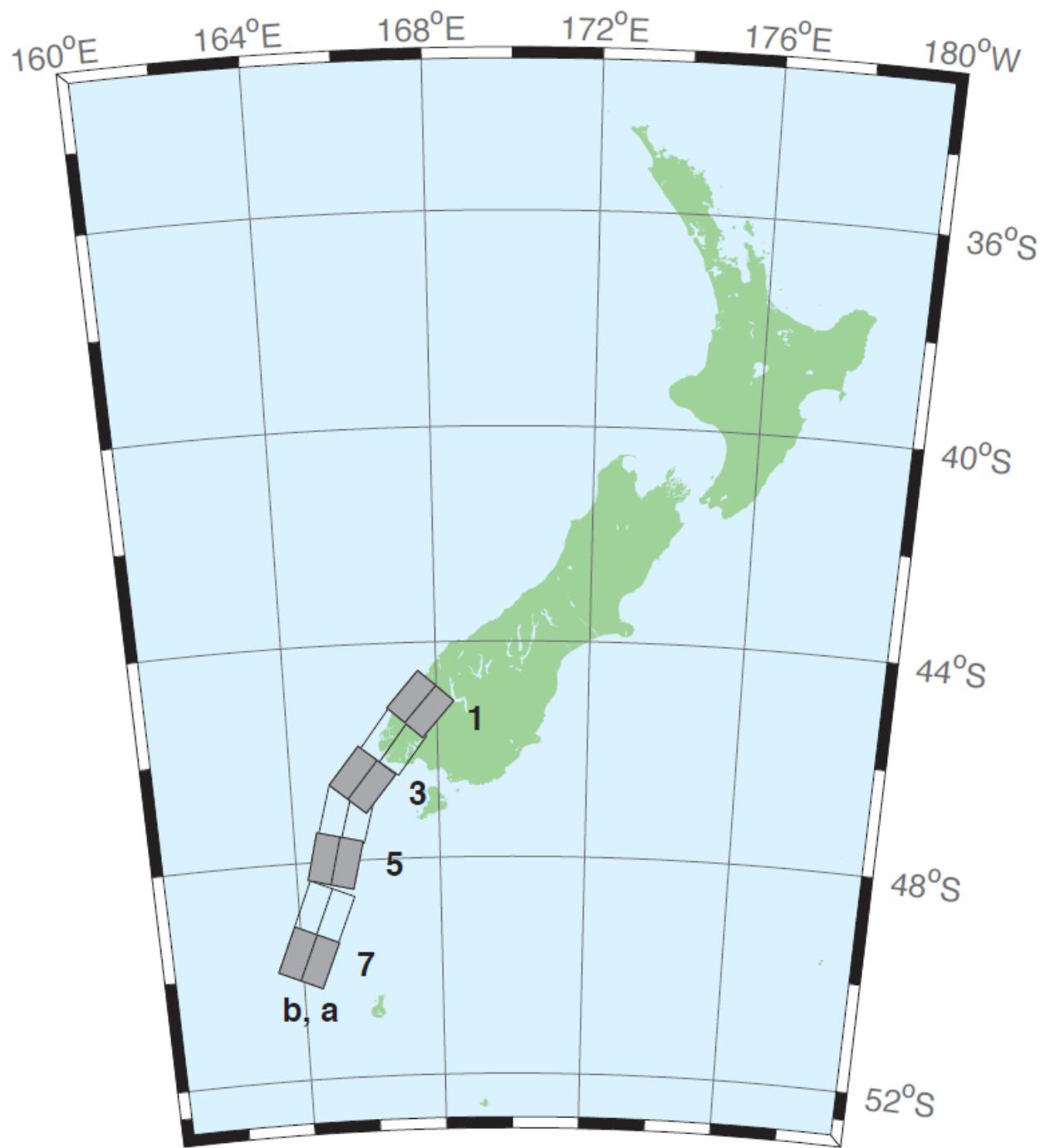


Figure 134. New Zealand-Puyseger Zone unit sources.

Table 15. Earthquake parameters for New Zealand-Puyseger Subduction Zone unit sources.

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
nzsz-01a	New Zealand-Puyseger	168.0294	-45.4368	15.00	41.50	17.94
nzsz-01b	New Zealand-Puyseger	167.5675	-45.1493	15.00	41.50	5.00
nzsz-02a	New Zealand-Puyseger	167.3256	-46.0984	15.00	37.14	17.94
nzsz-02b	New Zealand-Puyseger	166.8280	-45.8365	15.00	37.14	5.00
nzsz-03a	New Zealand-Puyseger	166.4351	-46.7897	15.00	39.53	17.94
nzsz-03b	New Zealand-Puyseger	165.9476	-46.5136	15.00	39.53	5.00
nzsz-04a	New Zealand-Puyseger	166.0968	-47.2583	15.00	15.38	17.94
nzsz-04b	New Zealand-Puyseger	165.4810	-47.1432	15.00	15.38	5.00
nzsz-05a	New Zealand-Puyseger	165.7270	-48.0951	15.00	13.94	17.94
nzsz-05b	New Zealand-Puyseger	165.0971	-47.9906	15.00	13.94	5.00
nzsz-06a	New Zealand-Puyseger	165.3168	-49.0829	15.00	22.71	17.94
nzsz-06b	New Zealand-Puyseger	164.7067	-48.9154	15.00	22.71	5.00
nzsz-07a	New Zealand-Puyseger	164.8017	-49.9193	15.00	23.25	17.94
nzsz-07b	New Zealand-Puyseger	164.1836	-49.7480	15.00	23.25	5.00

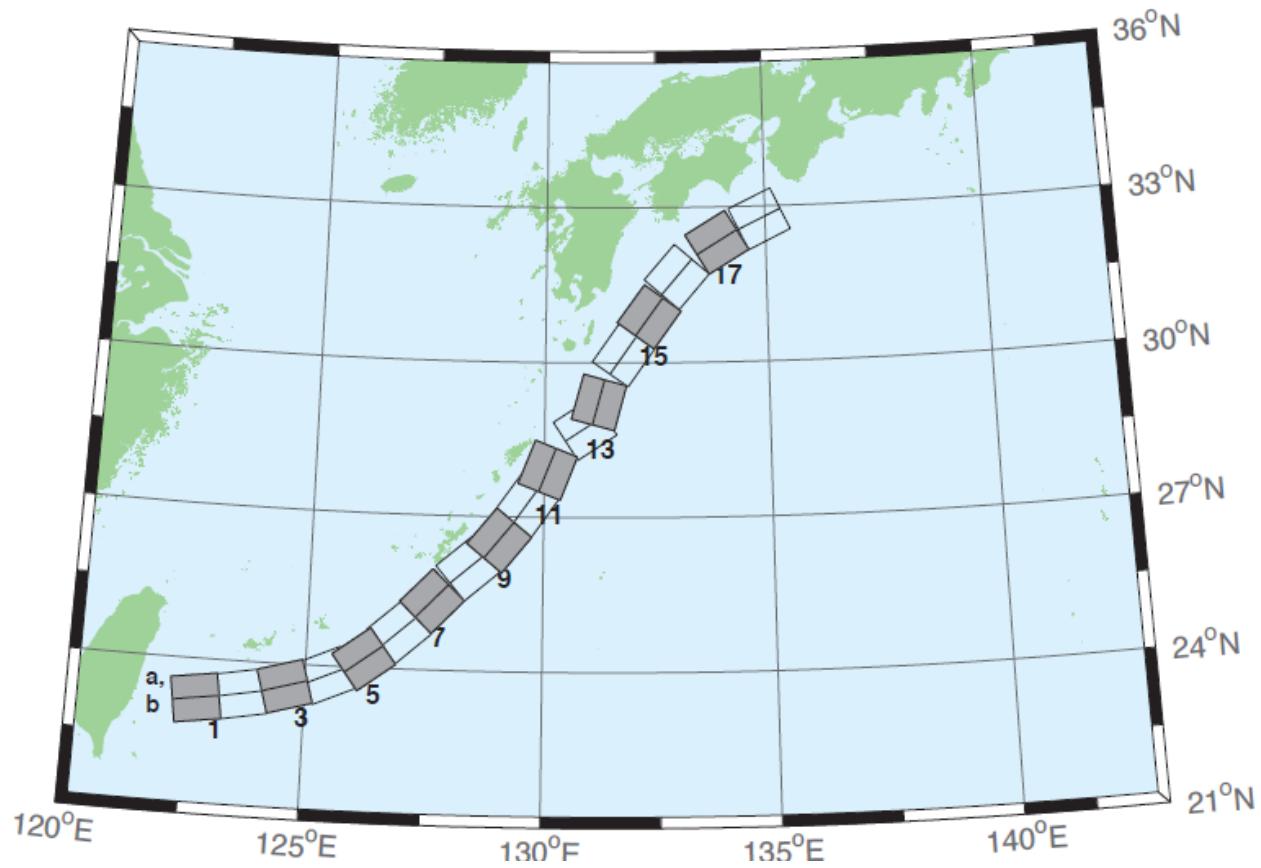


Figure 135. Ryukyu-Kyushu-Nankai Zone unit sources.

Table 16. Earthquake parameters for New Zealand-Puysegur Subduction Zone unit sources.

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
rnsz-01a	Ryukyu-Nankai	122.6672	23.6696	14.00	262.00	11.88
rnsz-01b	Ryukyu-Nankai	122.7332	23.2380	10.00	262.00	3.20
rnsz-02a	Ryukyu-Nankai	123.5939	23.7929	18.11	259.95	12.28
rnsz-02b	Ryukyu-Nankai	123.6751	23.3725	10.00	259.95	3.60
rnsz-03a	Ryukyu-Nankai	124.4604	23.9777	19.27	254.63	14.65
rnsz-03b	Ryukyu-Nankai	124.5830	23.5689	12.18	254.63	4.10
rnsz-04a	Ryukyu-Nankai	125.2720	24.2102	18.00	246.75	20.38
rnsz-04b	Ryukyu-Nankai	125.4563	23.8177	16.00	246.75	6.60
rnsz-05a	Ryukyu-Nankai	125.9465	24.5085	18.00	233.64	20.21
rnsz-05b	Ryukyu-Nankai	126.2241	24.1645	16.00	233.64	6.43
rnsz-06a	Ryukyu-Nankai	126.6349	25.0402	17.16	228.73	19.55
rnsz-06b	Ryukyu-Nankai	126.9465	24.7176	15.16	228.73	6.47
rnsz-07a	Ryukyu-Nankai	127.2867	25.6343	15.85	224.04	17.98
rnsz-07b	Ryukyu-Nankai	127.6303	25.3339	13.56	224.04	6.26
rnsz-08a	Ryukyu-Nankai	128.0725	26.3146	14.55	229.69	14.31
rnsz-08b	Ryukyu-Nankai	128.3854	25.9831	9.64	229.69	5.94
rnsz-09a	Ryukyu-Nankai	128.6642	26.8177	15.40	219.24	12.62
rnsz-09b	Ryukyu-Nankai	129.0391	26.5438	8.00	219.24	5.66
rnsz-10a	Ryukyu-Nankai	129.2286	27.4879	17.00	215.21	12.55
rnsz-10b	Ryukyu-Nankai	129.6233	27.2402	8.16	215.21	5.45
rnsz-11a	Ryukyu-Nankai	129.6169	28.0741	17.00	201.30	12.91
rnsz-11b	Ryukyu-Nankai	130.0698	27.9181	8.80	201.30	5.26
rnsz-12a	Ryukyu-Nankai	130.6175	29.0900	16.42	236.69	13.05
rnsz-12b	Ryukyu-Nankai	130.8873	28.7299	9.57	236.69	4.74
rnsz-13a	Ryukyu-Nankai	130.7223	29.3465	20.25	195.18	15.89
rnsz-13b	Ryukyu-Nankai	131.1884	29.2362	12.98	195.18	4.66
rnsz-14a	Ryukyu-Nankai	131.3467	30.3899	22.16	215.11	19.73
rnsz-14b	Ryukyu-Nankai	131.7402	30.1507	17.48	215.11	4.71
rnsz-15a	Ryukyu-Nankai	131.9149	31.1450	15.11	216.04	16.12
rnsz-15b	Ryukyu-Nankai	132.3235	30.8899	13.46	216.04	4.48
rnsz-16a	Ryukyu-Nankai	132.5628	31.9468	10.81	220.90	10.88
rnsz-16b	Ryukyu-Nankai	132.9546	31.6579	7.19	220.90	4.62
rnsz-17a	Ryukyu-Nankai	133.6125	32.6956	10.14	238.96	12.01
rnsz-17b	Ryukyu-Nankai	133.8823	32.3168	8.41	238.96	4.70
rnsz-18a	Ryukyu-Nankai	134.6416	33.1488	10.99	244.70	14.21
rnsz-18b	Ryukyu-Nankai	134.8656	32.7502	10.97	244.47	4.70

Table 16. continued

Segment	Description	Longitude (°)	Latitude (°)	Strike (°)	Dip (°)	Depth (km)
rnsz-19a	Ryukyu-Nankai	135.6450	33.5008	14.49	246.46	14.72
rnsz-19b	Ryukyu-Nankai	135.8523	33.1021	11.87	246.46	4.44
rnsz-20a	Ryukyu-Nankai	136.5962	33.8506	15.00	244.77	14.38
rnsz-20b	Ryukyu-Nankai	136.8179	33.4581	12.00	244.77	3.98
rnsz-21a	Ryukyu-Nankai	137.2252	34.3094	15.00	231.90	15.40
rnsz-21b	Ryukyu-Nankai	137.5480	33.9680	12.00	231.90	5.00
rnsz-22a	Ryukyu-Nankai	137.4161	34.5249	15.00	192.27	15.40
rnsz-22b	Ryukyu-Nankai	137.9301	34.4327	12.00	192.27	5.00

## **Appendix C. Forecast Model tests in SIFT system.**

The development of the Forecast models requires that it can provide a reliable and stable for several hours of simulation. This is accomplished by testing the forecast model with a set of synthetic tsunami events covering a range of tsunami source locations and magnitudes. Testing is also done with selected historical tsunami events when available.

The purpose of testing the forecast model testing is three-fold. The first objective is to assure that the results obtained with NOAA's tsunami forecast system, which has been released to the Tsunami Warning Centers for operational use, are similar to those obtained by the researcher during the development of the forecast model. The second objective is to test the forecast model for consistency, accuracy, time efficiency, and quality of results over a range of possible tsunami locations and magnitudes. The third objective is to identify bugs and issues in need of resolution by the researcher who developed the Forecast Model or by the forecast software development team before the next version release to NOAA's two Tsunami Warning Centers.

Local hardware and software applications, and tools familiar to the researcher(s), are used to run the Method of Splitting Tsunamis (MOST) model during the forecast model development. The test results presented in this section lend confidence that the model performs as developed and produces the same results when initiated within the forecast application in an operational setting as those produced by the researcher during the forecast model development. The test results assure those who rely on the Palm Beach, Florida tsunami forecast model that consistent results are produced irrespective of system.

### **C.1 Testing Procedure**

The general procedure for forecast model testing is to run a set of synthetic tsunami scenarios and a selected set of historical tsunami events through the forecast system application and compare the results with those obtained by the researcher during the forecast model development as presented in the Tsunami Forecast Model Report. Specific steps taken to test the model include:

1. Identification of testing scenarios, including the standard set of synthetic events, appropriate historical events, and customized synthetic scenarios that may have been used by the researcher(s) in developing the forecast model.
2. Creation of new events to represent customized synthetic scenarios used by the researcher(s) in developing the forecast model, if any.
3. Submission of test model runs with the forecast system, and export of the results from A, B, and C grids, along with time series.
4. Recording applicable metadata, including the specific version of the forecast system used for testing.
5. Examination of forecast model results for instabilities in both time series and plot results.
6. Comparison of forecast model results obtained through the forecast system with those obtained during the forecast model development.
7. Summarization of results with specific mention of quality, consistency, and time efficiency.

8. Reporting of issues identified to modeler and forecast software development team.
9. Retesting the forecast models in the forecast system when reported issues have been address or explained.
10. Simulation of the Synthetic model were tested on a DELL PowerEdge R510 computer equipped with two Xeon E5670 processors at 2.93 GHz, each with 12 MBytes of cache and 32GB memory. The processors are hex core and support hyper-threading, resulting in the computer performing as a 24 processor core machine. Additionally, the testing computer supports 10 Gigabit Ethernet for fast network connections. This computer configuration is similar or the same as the configurations of the computers installed at the Tsunami Warning Centers so the compute times should only vary slightly

## C.2 Results

The Hanalei forecast model was tested with NOAA's tsunami forecast system version 3.2.

The Hanalei forecast model was tested with four synthetic scenarios and one historical tsunami event. Test results from the forecast system and comparisons with the results obtained during the forecast model development are shown numerically in Table 17 and graphically in Figures 136 to 140. The results show that the forecast model is stable and robust, with consistent and high quality results across geographically distributed tsunami sources and mega-event tsunami magnitudes. The model run time (wall clock time) was under 13.6 minutes for 6 hours of simulation time, and under 9.1 minutes for 4 hours. This run time is within the 10 minute run time for 4 hours of simulation time and satisfies time efficiency requirements.

Four synthetic events were run on the Hanalei forecast model. A slip of 30m was used rather than the standard 25m for direct comparison purposes. The modeled scenarios were stable for all cases tested, with no instabilities or ringing. Amplitudes greater than 100 centimeters (cm) were recorded for all test cases. The largest modeled amplitude was 391 cm and originated in the Aleutian-Alaska-Cascadia (ACSZ 56-65) source. The smallest signal of 162 cm was recorded at the Central and South America (CSSZ 91-100) source. The largest modeled tsunami wave amplitude indicated in this section is based only from the four synthetic events (Table 17) and does not represent the largest tsunami wave amplitude from the 42 tested during its development. The maximum and minimum tsunami amplitude obtained during the forecast model development differs from the ones tested with the tsunami forecast system. This could be attributed to some updates in the propagation database when the SIFT testing was conducted. Overall, direct comparisons of output from the forecast tool with results of both the Tohoku (Honshu in the report) 2011 historical event and available development synthetic events, demonstrated that the wave pattern were nearly identical in shape, pattern and amplitude.

Table 17. Table of maximum and minimum amplitudes (cm) at the Hanalei, Hawai‘i warning point for synthetic and historical events tested using SIFT 3.2 and obtained during development.

Scenario Name	Source Zone	Tsunami Source	$\alpha$ [m]	SIFT Max (cm)	Development Max (cm)	SIFT Min (cm)	Development Min (cm)
<b>Mega-tsunami Scenarios</b>							
KISZ 22-31	Kamchatka-Yap-Mariana-Izu-Bonin	A22-A31, B22-B31	30	355.8	342.3	-150.0	-160.0
ACSZ 56-65	Aleutian-Alaska-Cascadia	A56-A65, B56-B65	30	390.6	398.5	-149.7	-160.0
CSSZ 91-100	Central and South America	A91-A100, B91-B100	30	162.2	161.7	-149.7	-160.0
NTSZ 30-39	New Zealand-Kermadec-Tonga	A30-A39, B30-B39	30	338.5	338.9	-150.0	-160.0
<b>Historical Events</b>							
Tohoku (or Honshu) 2011	Kamchatka-Yap-Mariana-Izu-Bonin	See Table 3		186.8	119.7	-145.3	-136.7

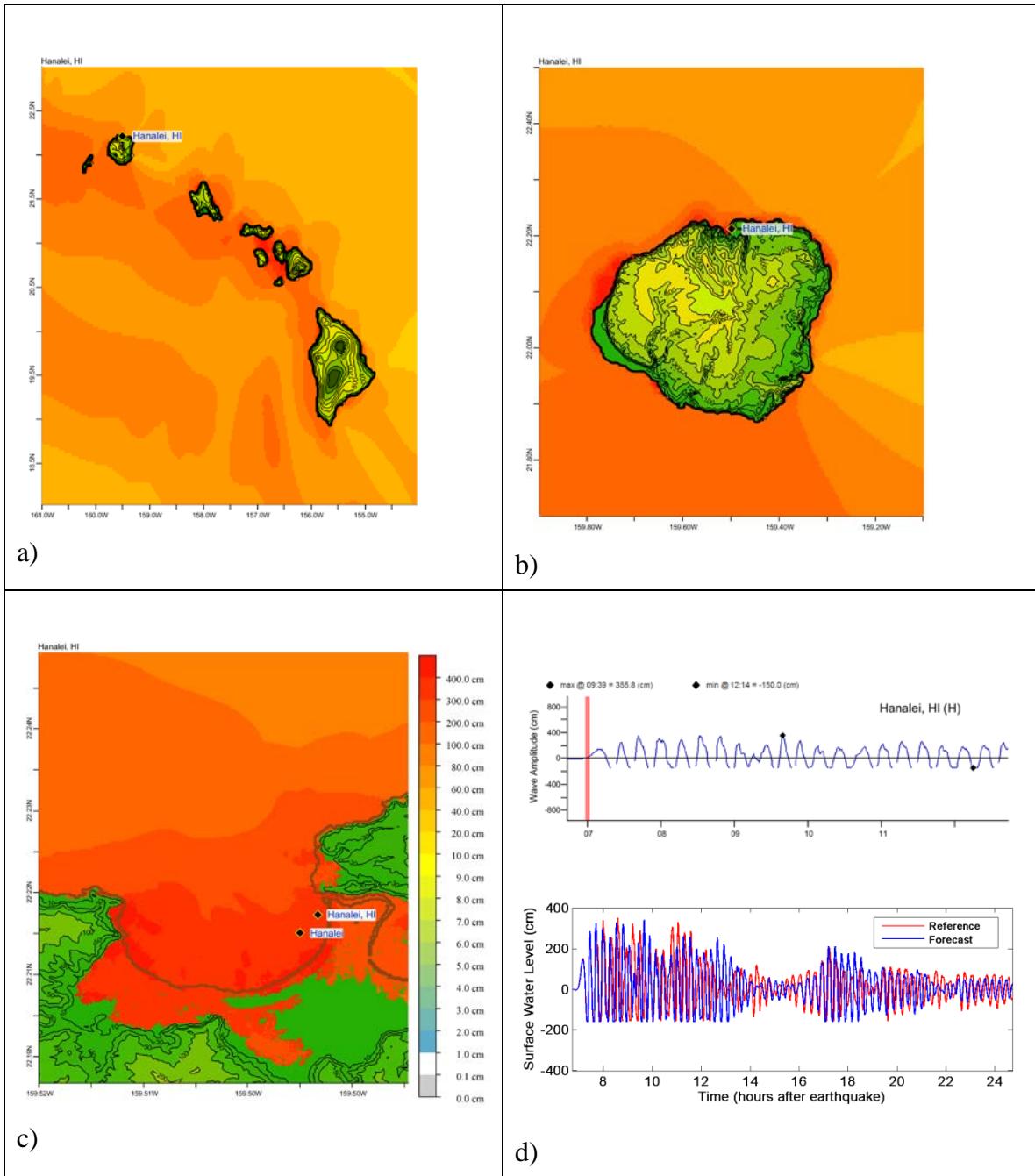


Figure 136. Response of the Hanalei, Hawai'i forecast model to synthetic scenario KISZ 22-31 (alpha=30). Maximum sea surface elevation for (a) A-grid, (b) B-grid, (c) C-grid. Sea surface elevation time series at the C-grid warning point (d). The lower time series plot is the result obtained during model development and is shown for comparison with test results.

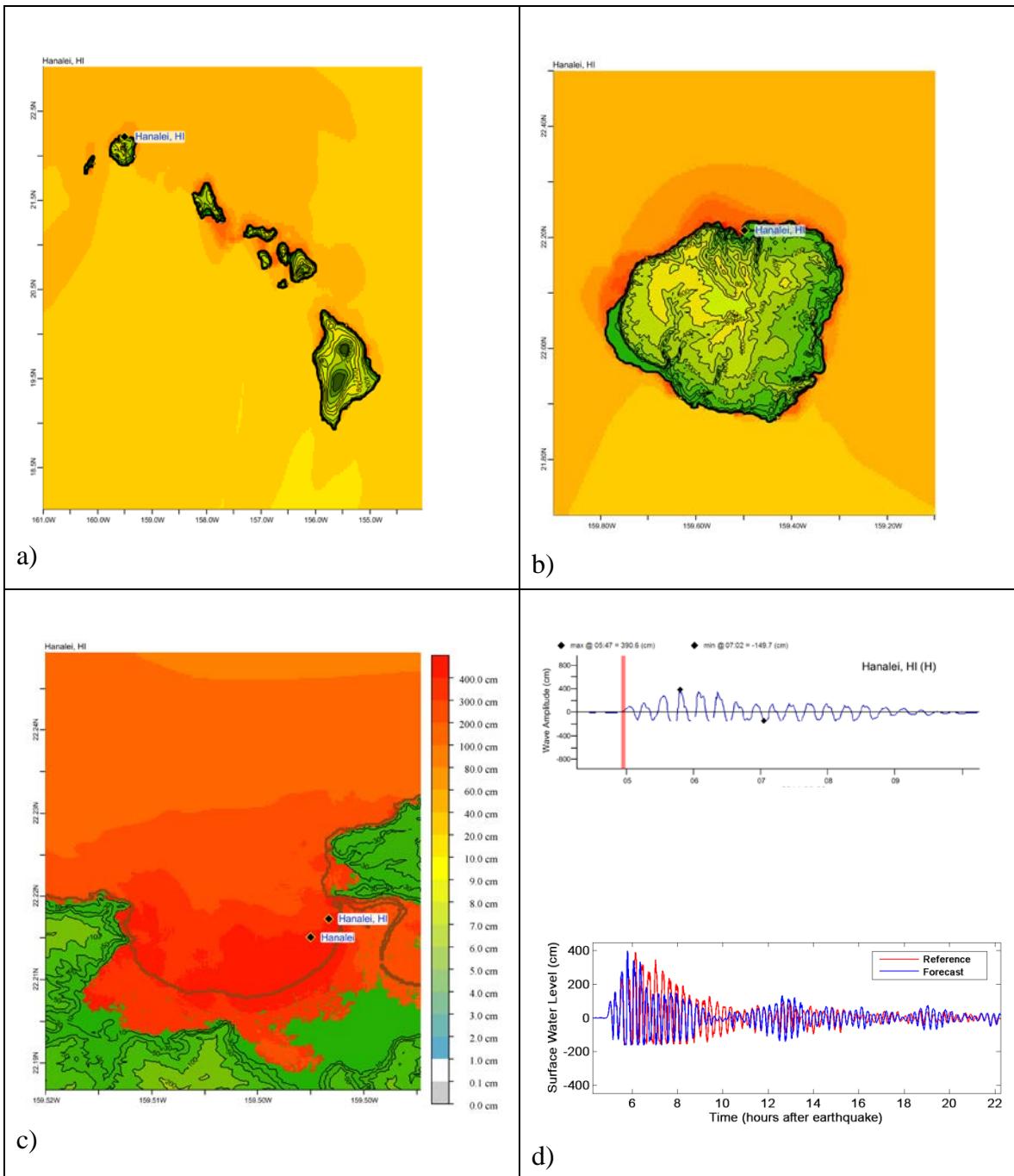


Figure 137. Response of the Hanalei, Hawai'i forecast model to synthetic scenario ACSZ 56-65 ( $\alpha=30$ ). Maximum sea surface elevation for (a) A-grid, (b) B-grid, (c) C-grid. Sea surface elevation time series at the C-grid warning point (d). The lower time series plot is the result obtained during model development and is shown for comparison with test results.

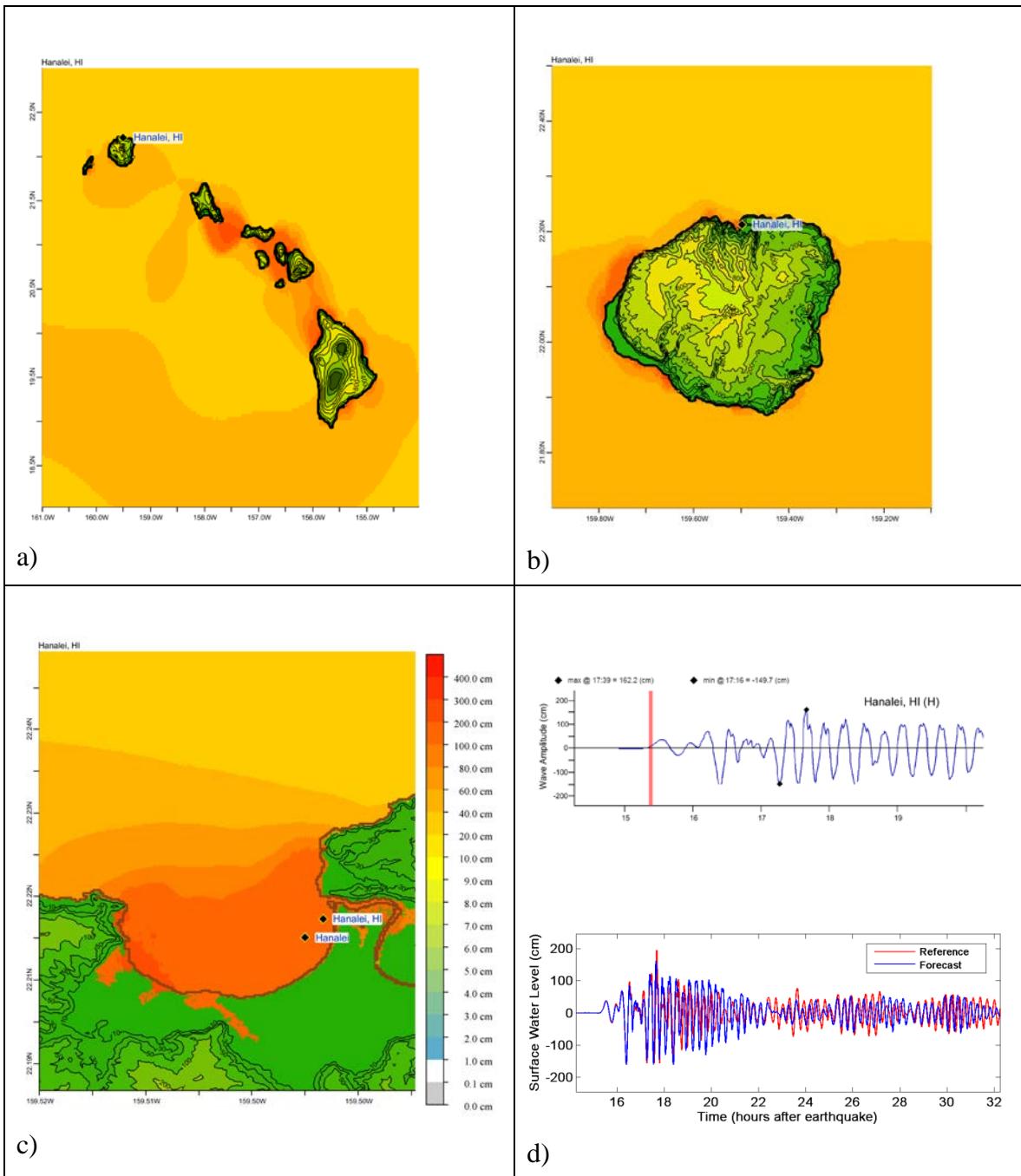


Figure 138. Response of the Hanalei, Hawai'i forecast model to synthetic scenario CSSZ 91-100 (alpha=30). Maximum sea surface elevation for (a) A-grid, b) B-grid, c) C-grid. Sea surface elevation time series at the C-grid warning point (d). The lower time series plot is the result obtained during model development and is shown for comparison with test results.

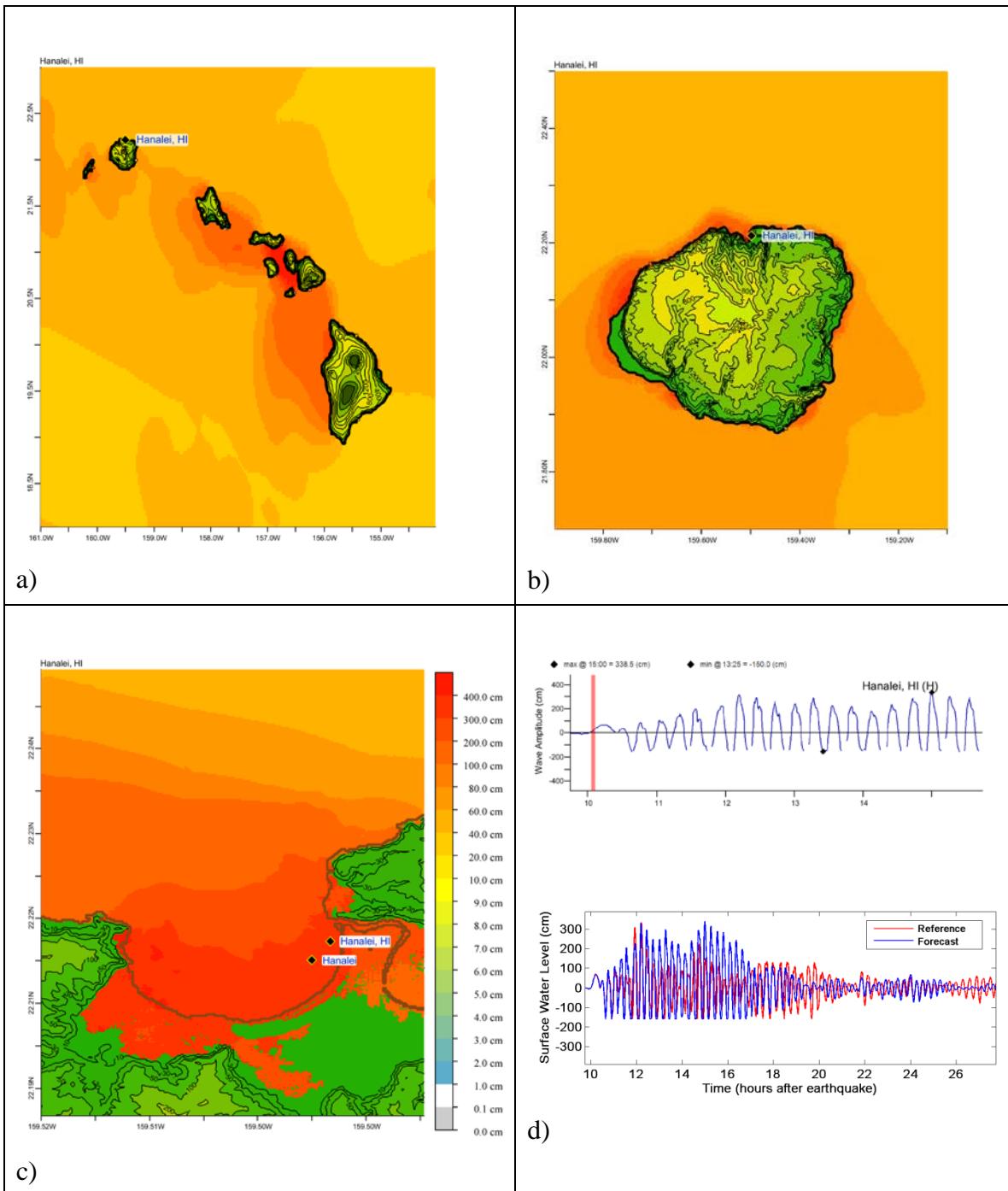


Figure 139. Response of the Hanalei, Hawai'i forecast model to synthetic scenario NTSZ 30-39 (alpha=30). Maximum sea surface elevation for (a) A-grid, (b) B-grid, (c) C-grid. Sea surface elevation time series at the C-grid warning point (d). The lower time series plot is the result obtained during model development and is shown for comparison with test results.

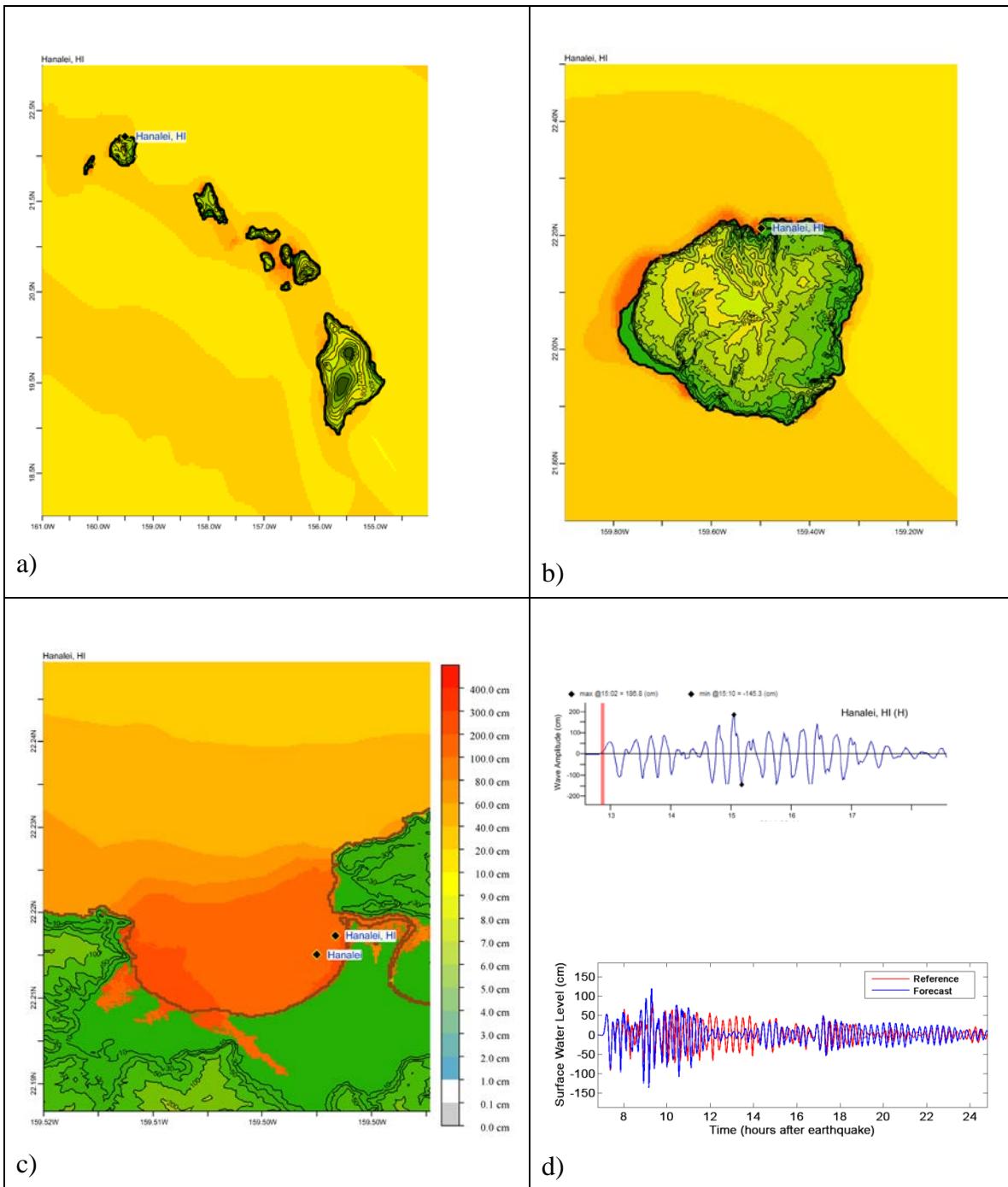


Figure 140. Response of the Hanalei, Hawai'i forecast model to the 2011 Tohoku tsunami. Maximum sea surface elevation for (a) A-grid, b) B-grid, c) C-grid. Sea surface elevation time series at the C-grid warning point (d). The lower time series plot is the result obtained during model development and is shown for comparison with test results.