New Seismic Activity Model of Large Earthquakes along Nankai Trough for Probabilistic Seismic Hazard Maps

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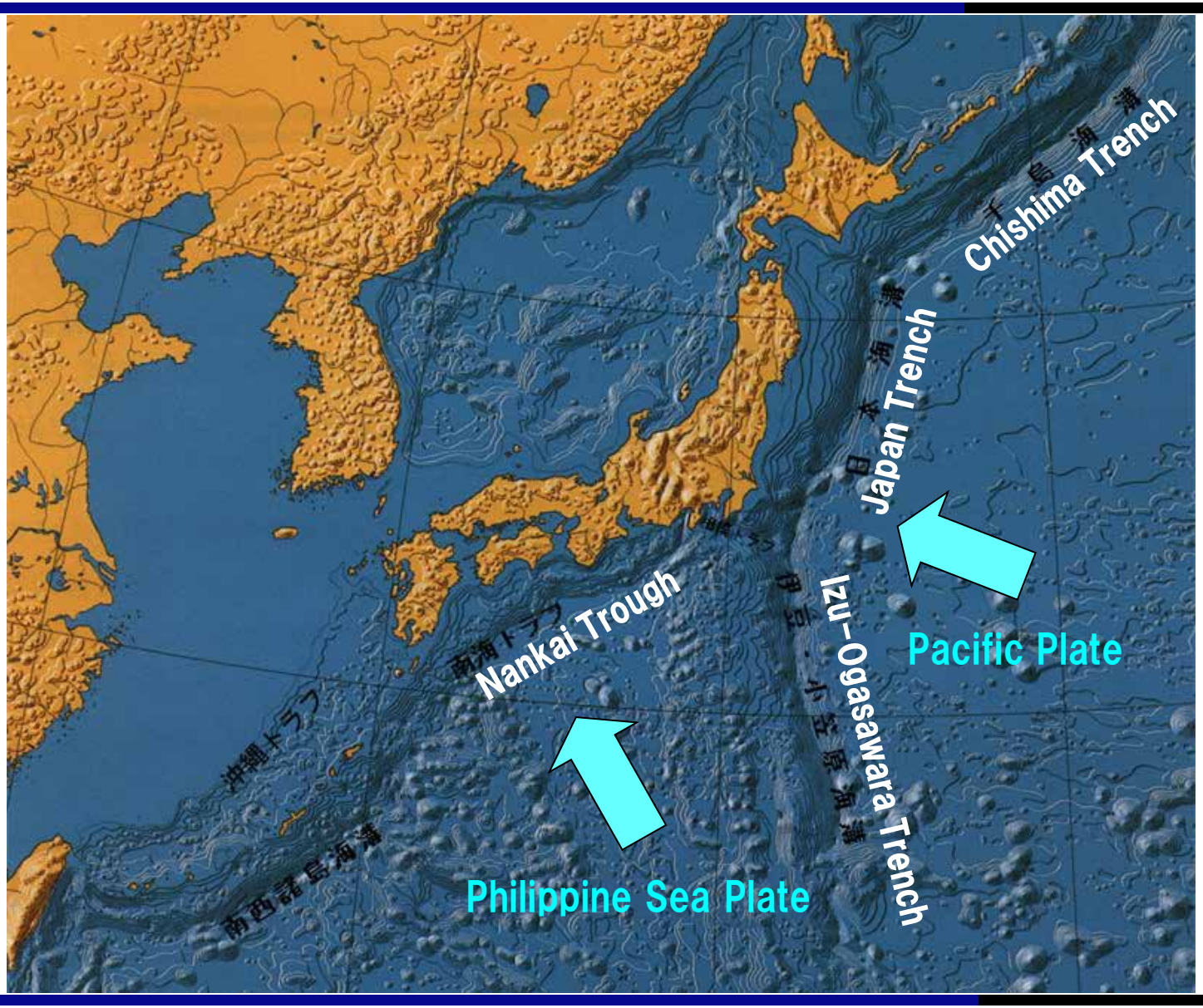
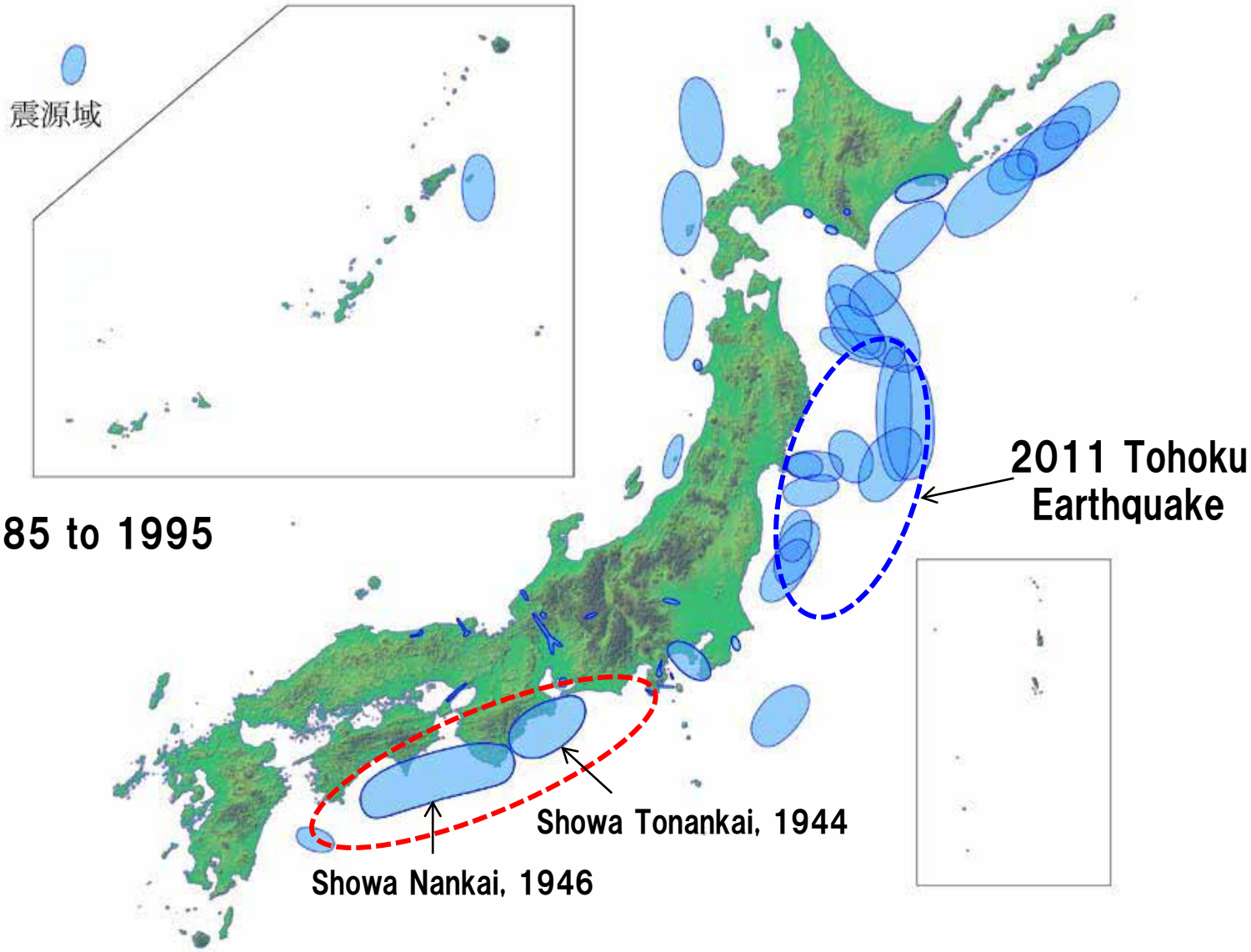
Plate Tectonics around Japan



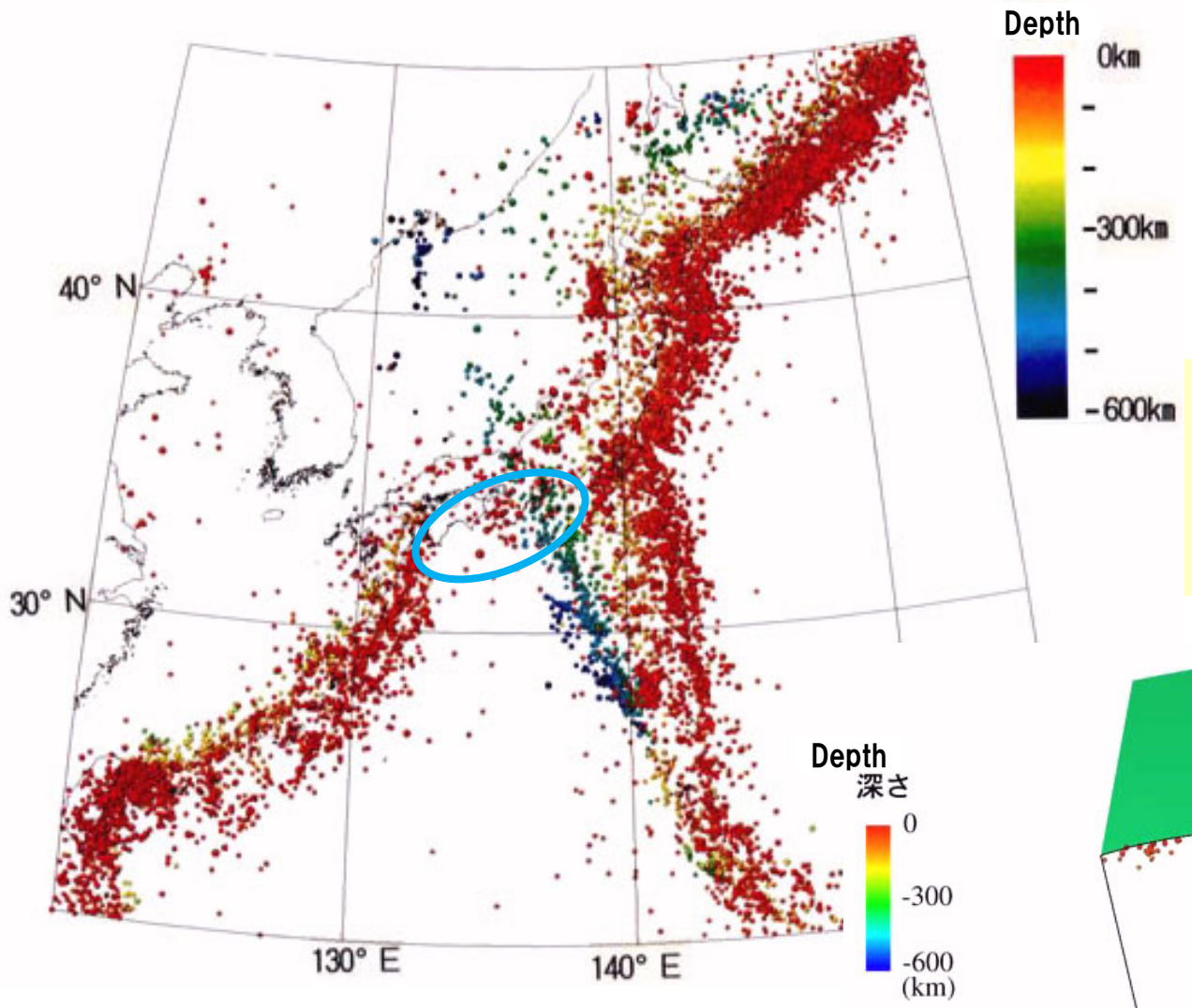
after *Japan Coast Guard*

Source Area of Damaging Earthquakes



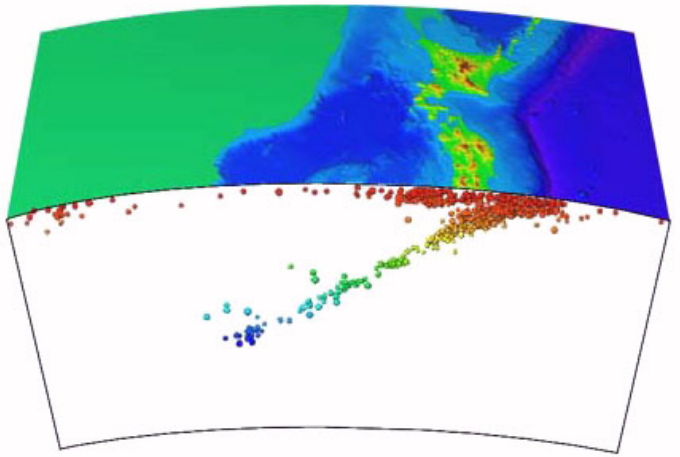
Earthquake Research Committee (1999):Seismic Activity in Japan

Earthquakes in and around Japan



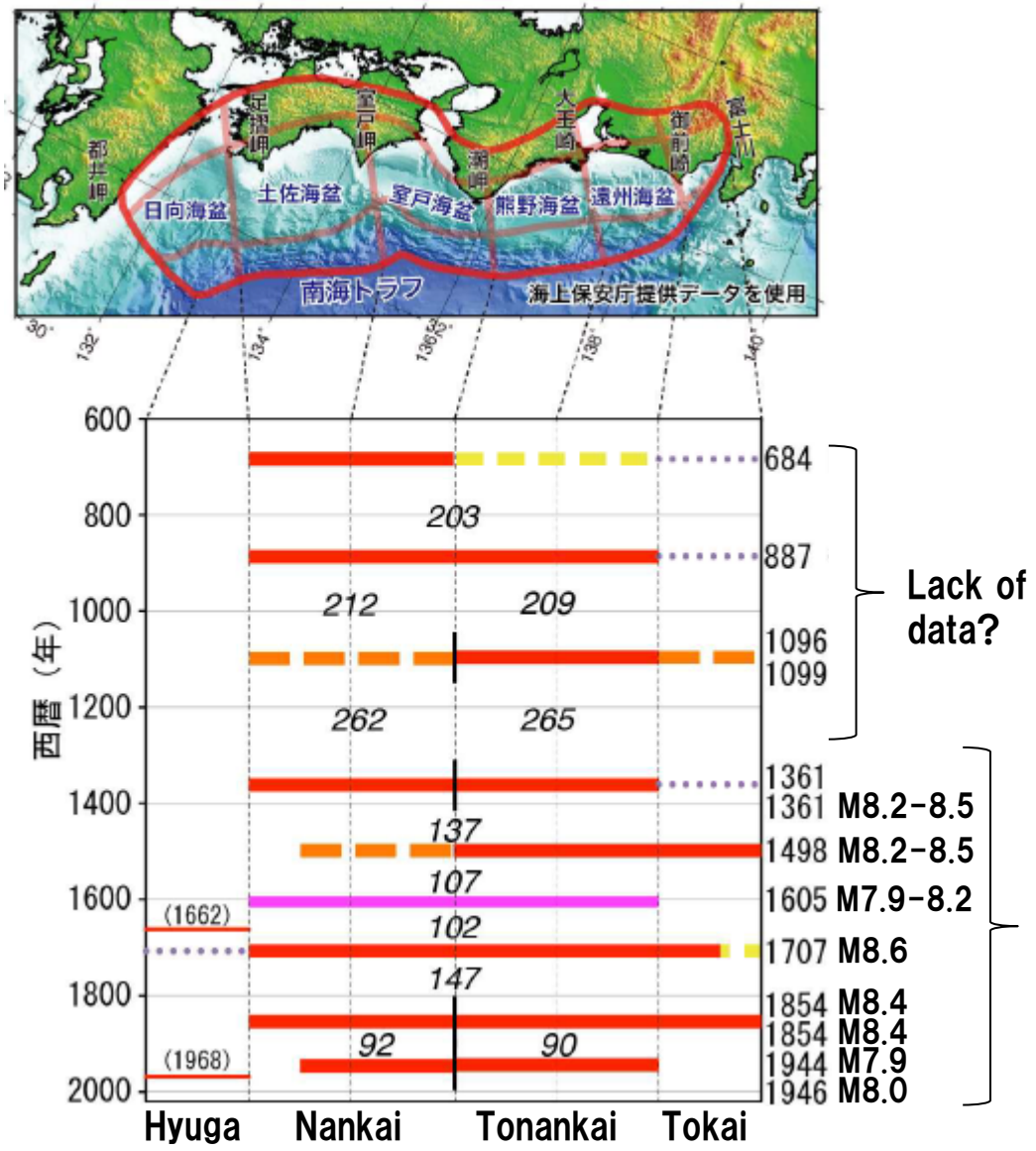
1904～1995
M≧4.5

Seismic activity of small to middle size earthquakes along Nankai Trough is NOT high



Earthquake Research Committee (1999):Seismic Activity in Japan

Large Earthquakes along Nankai Trough



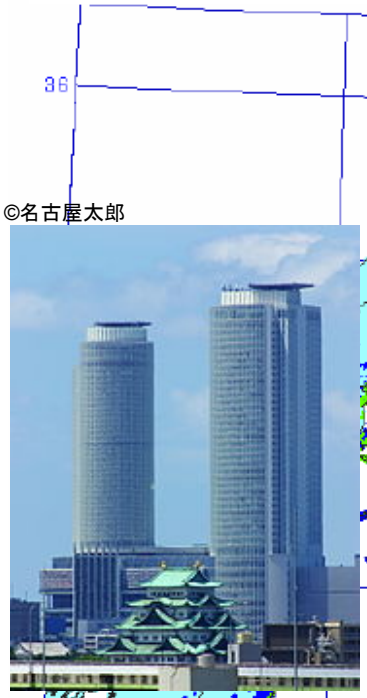
Lack of data?

Interval: 90-150 years
(Average=117yrs)

- Large earthquakes (M≧8) have occurred repeatedly with recurrence interval 90-150 yrs
- One huge earthquake or two successive earthquakes with interval of 1day to 3yrs
- Source area often reaches to Tokai area
- Tokai area has never caused earthquake independently

Earthquake Research Committee (2013)

Affected Area of Nankai Trough EQs



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Affected area includes:

- Large cities
  - Osaka: 2.7mill.
  - Nagoya: 2.3mill.
  - Hamamatsu: 0.8mill.
  - Shizuoka: 0.7mill.
- Industrial belt
- Important traffic lines

Cabinet Office (2004)

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Long-Term Evaluation（2001）

Evaluation of occurrence potentials for Nankai and Tonankai earthquakes

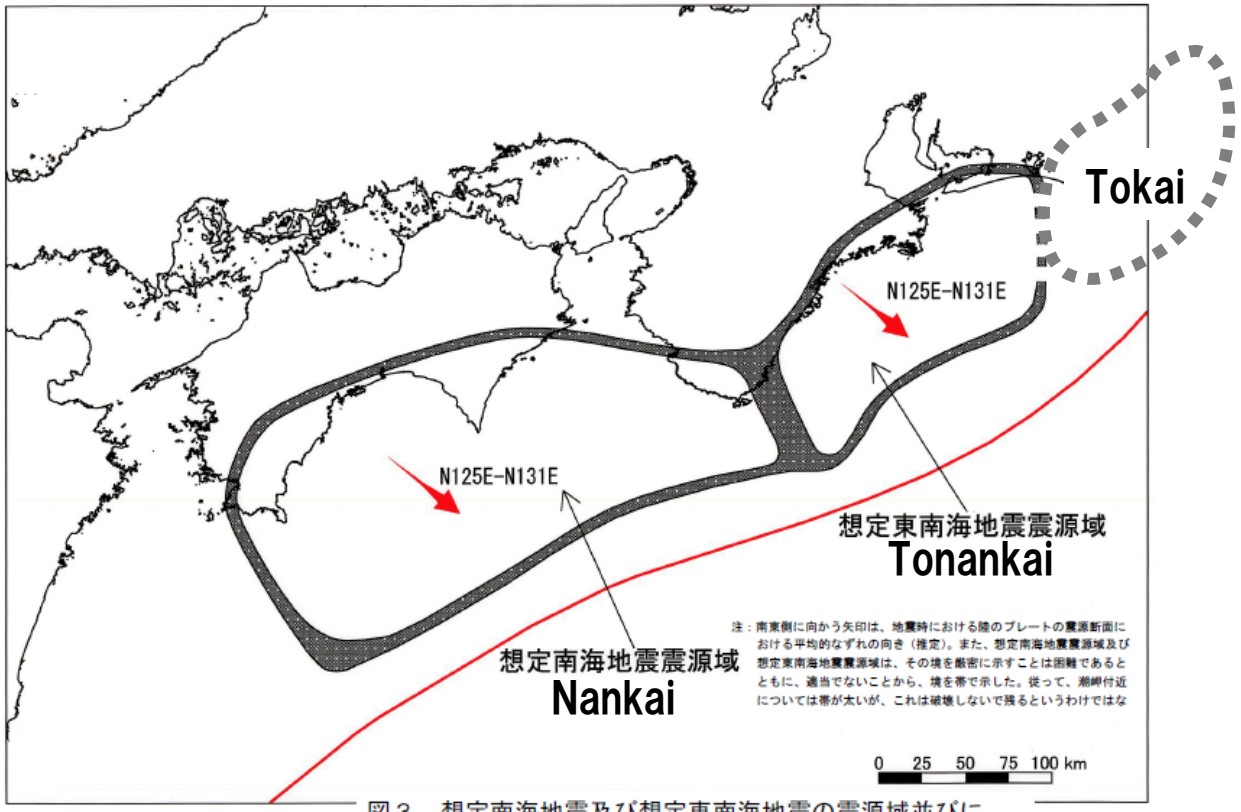


図３　想定南海地震及び想定東南海地震の震源域並びに
想定地震発生時の震源域に想定される平均的なずれの向き

Earthquake Research Committee,
Headquarters for Earthquake Research Promotion（2001）

Time predictable mode:

Nankai Earthquake
- M≒8.4
- Tr=90.1yrs
- P_{30}≒60%（2012）

Tonankai Earthquake
- M≒8.1
- Tr=86.4yrs
- P_{30}≒70-80%（2012）

Nankai + Tonankai
- M≒8.5
- P_{30} : *not evaluated*

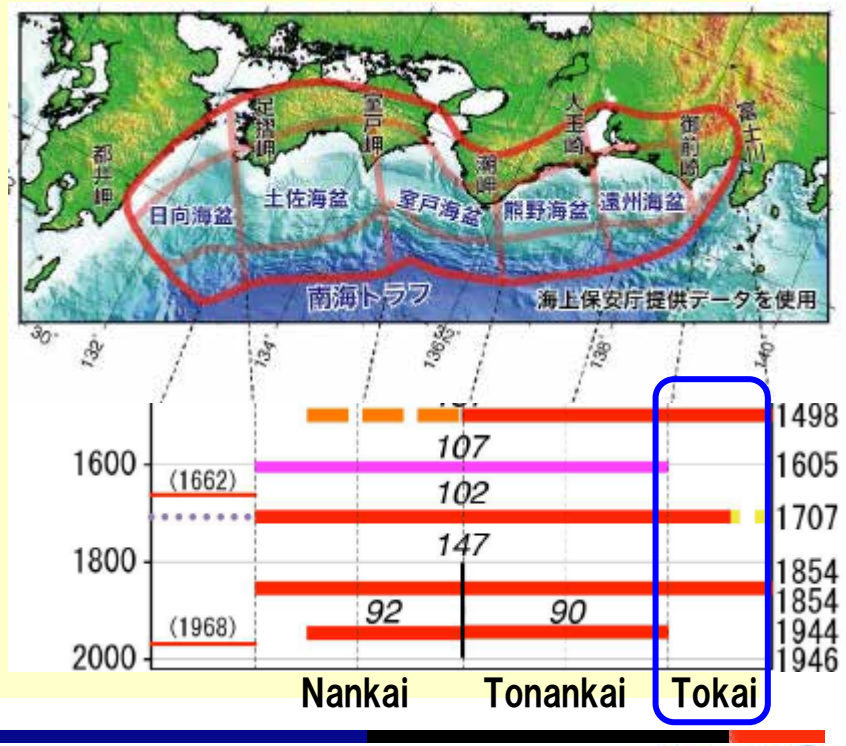
Tokai Earthquake
not evaluated

Addition to Long-Term Evaluation 2001

In order to perform probabilistic seismic hazard analysis, the followings were assumed:

- **Evaluation of Tokai area**
  - Average recurrence interval: 118.8 yrs (renewal process)
  - Elapsed time from the latest event: 157.0 yrs (1854)

  ⇒ P_{30}=88% (as of Jan. 2012)
  - M=8.0



Addition to Long-Term Evaluation 2001

In order to perform probabilistic seismic hazard analysis, the followings were assumed:

- **Probability that adjoining areas slip simultaneously to generate larger earthquakes**
  - When both of adjoining two areas cause earthquakes within 30 years, probability that they cause one large earthquake is **1/2.**

Model for Hazard Assessment

No.	Nankai M=8.4 P30=62%	Tonankai M=8.1 P30=72%	Tokai M=8.0 P30=88%	Probability in 30 years
(1)	×	×	×	1.3%
(2)	⟷	×	×	2.2%
(3)	×	⟷	×	3.4%
(4)	×	×	⟷	9.3%
(5)	⟷	⟷	×	2.8%
(6)	⟷	⟷	×	2.8%
(7)	⟷	×	⟷	15%
(8)	×	⟷	⟷	12%
(9)	×	⟷	⟷	12%
(10)	⟷	⟷	⟷	9.8%
(11)	⟷	⟷	⟷	9.8%
(12)	⟷	⟷	⟷	9.8%
(13)	⟷	⟷	⟷	9.8%
	Total			100%

these patterns are not observed

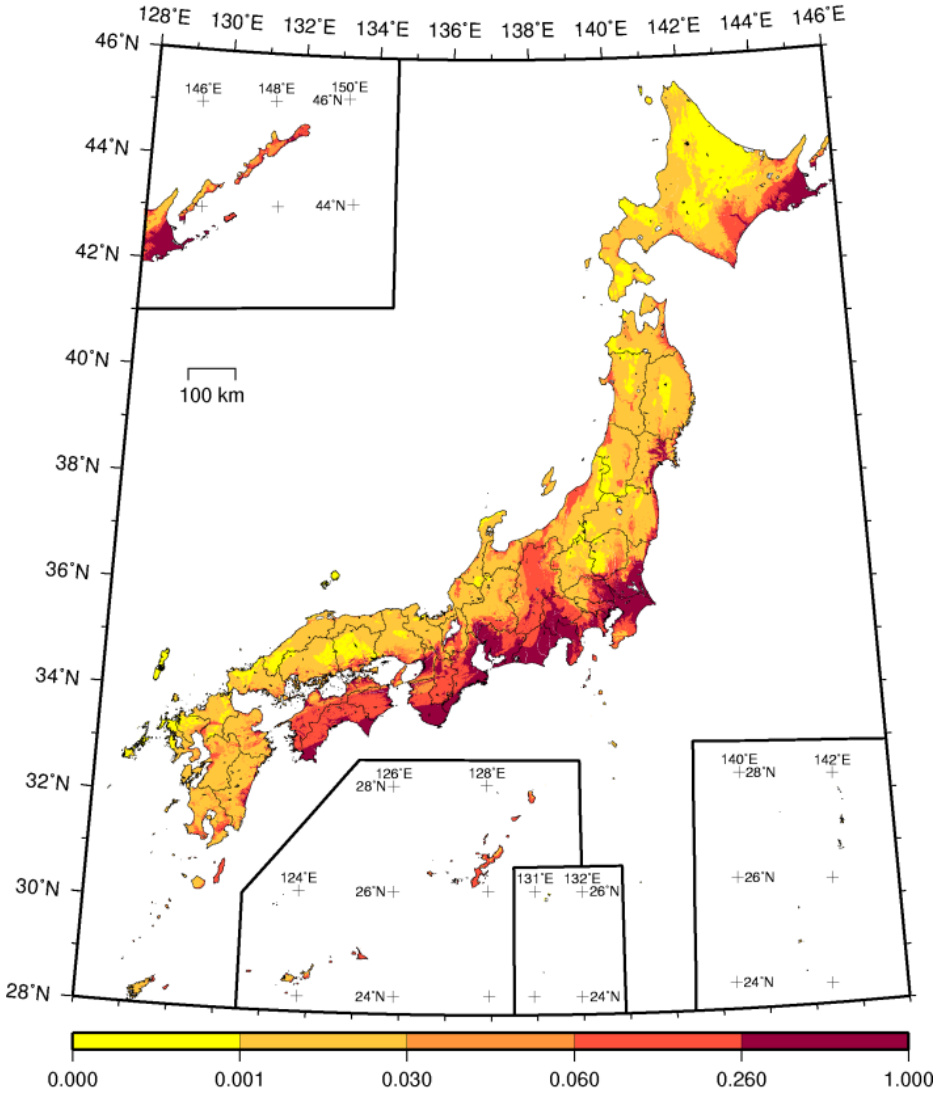
{(1−0.62)×0.72×0.88}/2=0.12

(0.62×0.72×0.88)/4=0.098

⟷ two or more areas slip simultaneously

Seismic Hazard Map 2012

Prob. that JMA seismic intensity is 6-Lower or greater in 30 years from 2012



Problems in Old Model

1. Three areas, Nankai, Toankai and Tokai are evaluated independently
   - large probability assigned to *odd* occurrence patterns

2. Possibility of occurrence of larger earthquakes is eliminated
   - need to incorporate lessens learned from Tohoku earthquake of 2011
   - evidence of large tsunami of 2000 years ago has been found recently

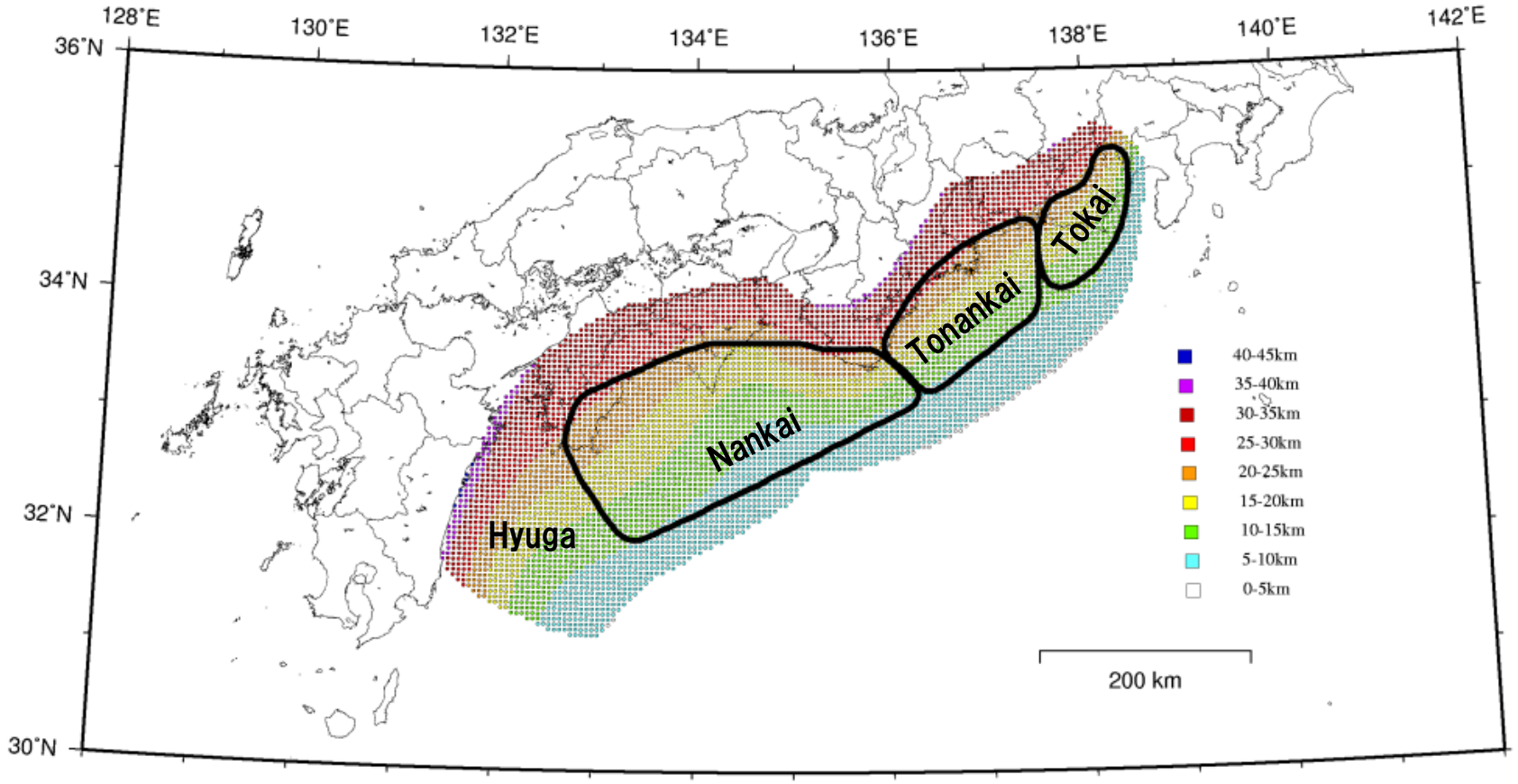
Revised Long-term Evaluation (May, 2013)

Earthquake Research Committee has published revised version of long-term evaluation of Nankai trough earthquakes

1. Possibility of larger earthquakes (up to M=9.1)
   - potential source area is expanded
2. Evaluation of earthquake(s) along whole the Nankai trough, not for individual areas
   - P_{30}=66.5% ⇔ Nankai:62%, Tonankai:72%, Tokai:88%
3. Diversity of future earthquakes
   - probability of occurrence of individual case is not shown

Source Area of Maximum Earthquake

- Source area is expanded to west (Hyuga area), south (shallow tsunami generating zone: 0-10km) and north (deep zone: 25-35km)



Earthquake Research Committee (2013)

Variation of Earthquakes

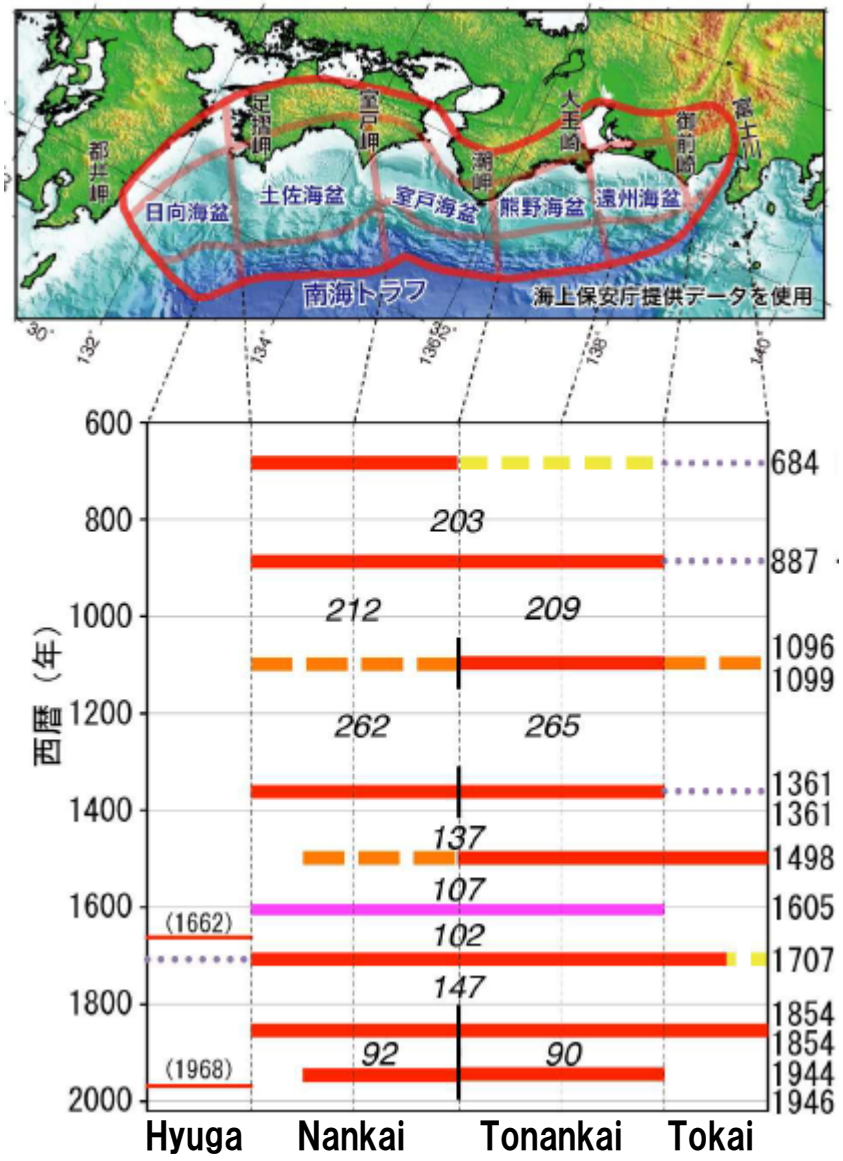
	深さ	推定破壊域 Z	A	B	C	D	E	スケーリング則から推定されるMw
東海・南海地域が連動するパターン	浅部							
	中部	■	■	■	■	■	■	8.8
	深部							
	浅部							
	中部	■	■	■	■	■	■	9.0*1
	深部	■	■	■	■	■	■	
	浅部	■	■	■	■	■	■	
	中部	■	■	■	■	■	■	9.0
	深部							
	浅部	■	■	■	■	■	■	
	中部	■	■	■	■	■	■	9.1*2
	深部	■	■	■	■	■	■	
	浅部							
	中部		■	■	■	■	■	8.7
	深部							
	浅部		■	■	■	■	■	
	中部		■	■	■	■	■	8.9
	深部							
	浅部							
	中部	■	■	■	■	■		8.8
	深部							
	浅部	■	■	■	■	■		
	中部	■	■	■	■	■		9.0
	深部							
	浅部							
	中部		■	■	■	■		8.7
	深部							
	浅部		■	■	■	■		
	中部		■	■	■	■		8.9
	深部							
	浅部		■	■	■	■		
	中部							8.4
	深部							

	深さ	推定破壊域 Z	A	B	C	D	E	スケーリング則から推定されるMw
東海・南海地域の2地震が時間差をおいて発生するパターン	浅部							
	中部	■	■	■	■	■	■	8.7, 8.3
	深部							
	浅部							
	中部		■	■	■	■	■	8.5, 8.3
	深部							
	浅部							
	中部	■	■	■	■	■		8.7, 8.2
	深部							
	浅部							
	中部		■	■	■	■		8.5, 8.2
	深部							

Earthquake Research Committee (2013)

SHIMIZU CORPORATION SHIMZ

Variation of Earthquakes



Assumptions to make a model:

- Prob. of 1EQ or 2EQs is even
- Nankai and Tonankai always slip
- when 2 EQs occur, source zone is divided between Nankai and Tonankai
- Prob. that source area reaches Tokai is 0.75
- Prob. of maximum EQ (Hyuga to Tokai) is 0.05

Earthquake Research Committee (2013)

Variation of Earthquakes

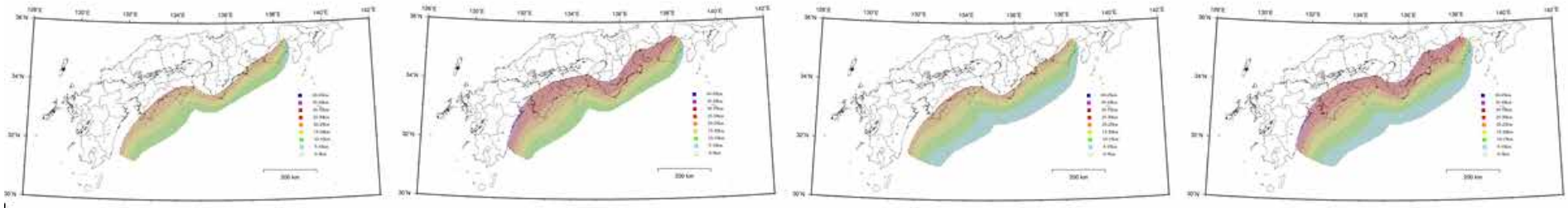
tentative

		Hyuga	Nankai	Tonankai	Tokai	Weight	*Mw*	Depth	
0.5	1 EQ	←	←	←	→	0.0125	8.8	-M-	0.05
		←	←	←	→	0.0125	9.0	-MD	
		←	←	←	→	0.0125	9.0	SM-	
		←	←	←	→	0.0125	9.1	SMD	
		×	←	←	→	0.1625	8.7	-M-	0.325
		×	←	←	→	0.1625	8.9	SM-	
		←	←	→	×	0.0125	8.8	-M-	0.025
		←	←	→	×	0.0125	9.0	SM-	
		×	←	→	×	0.025	8.7	-M-	0.10
		×	←	→	×	0.025	8.9	SM-	
		×	←	→	×	0.05	8.4	S--	
0.5	2 EQs	←	←	←	→	0.05	8.7, 8.3	-M-	
		×	←	←	→	0.325	8.5, 8.3	-M-	
		←	←	←	×	0.025	8.7, 8.2	-M-	
		×	←	←	×	0.1	8.5, 8.2	-M-	
		0.15	1.0	1.0	0.75	1.0			

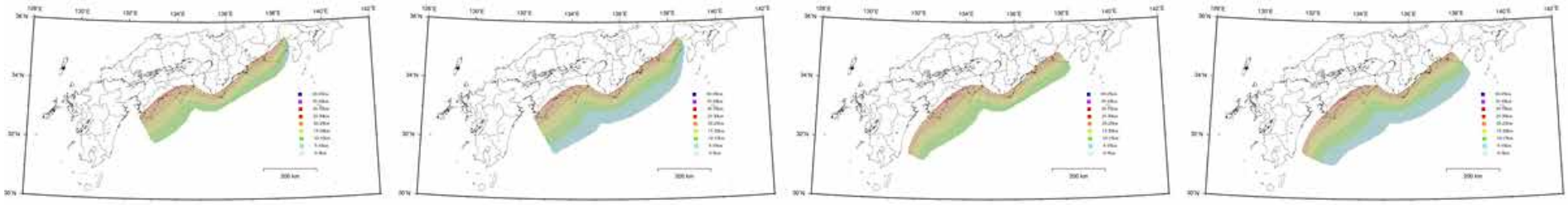
Depth S: 0-10km, M: 10-25km, D: 25-35km

Source Area of Earthquakes

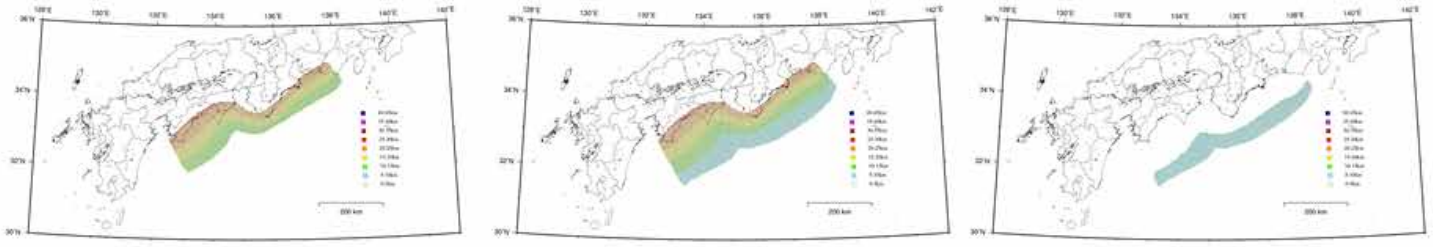
One Large Earthquake



Hyuga + Nankai + Tonankai + Tokai



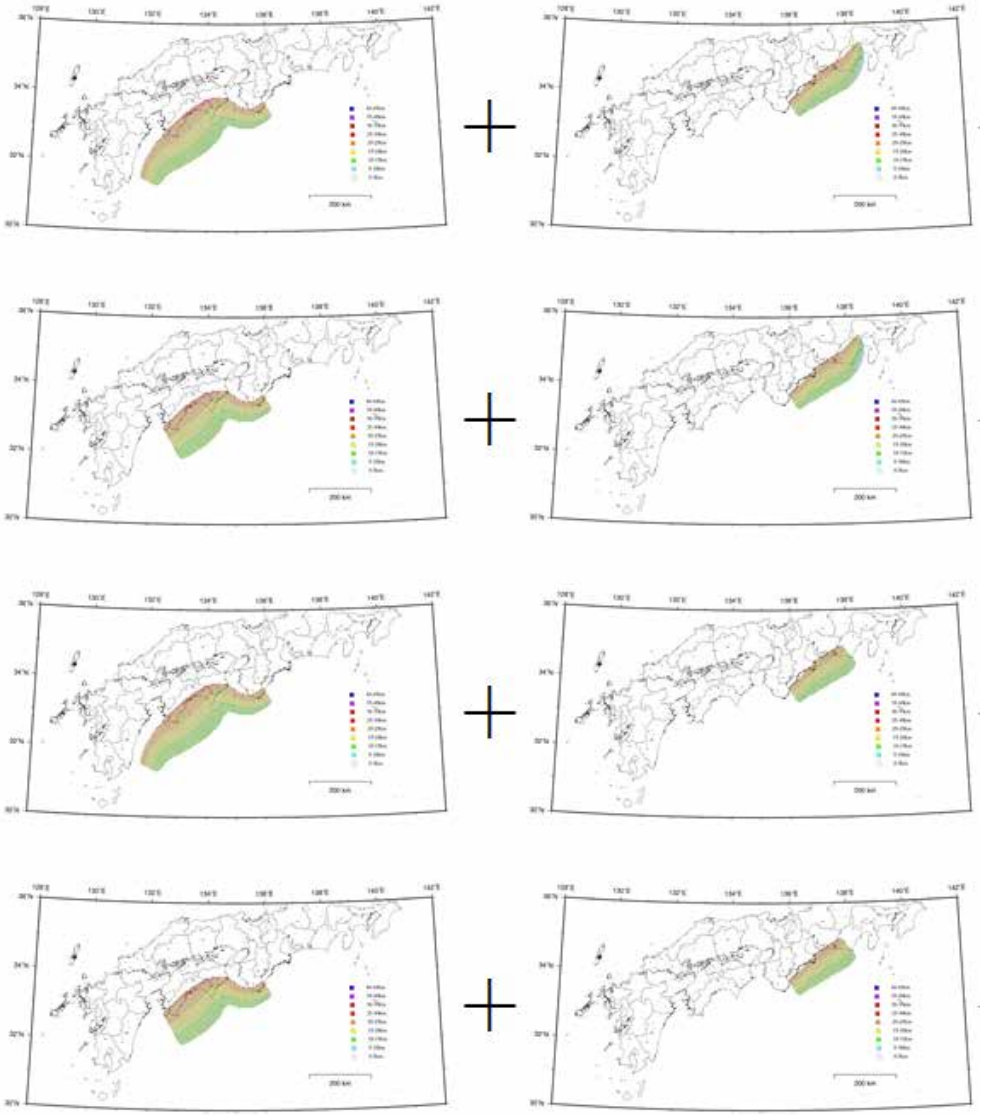
Nankai + Tonankai + Tokai



Nankai + Tonankai

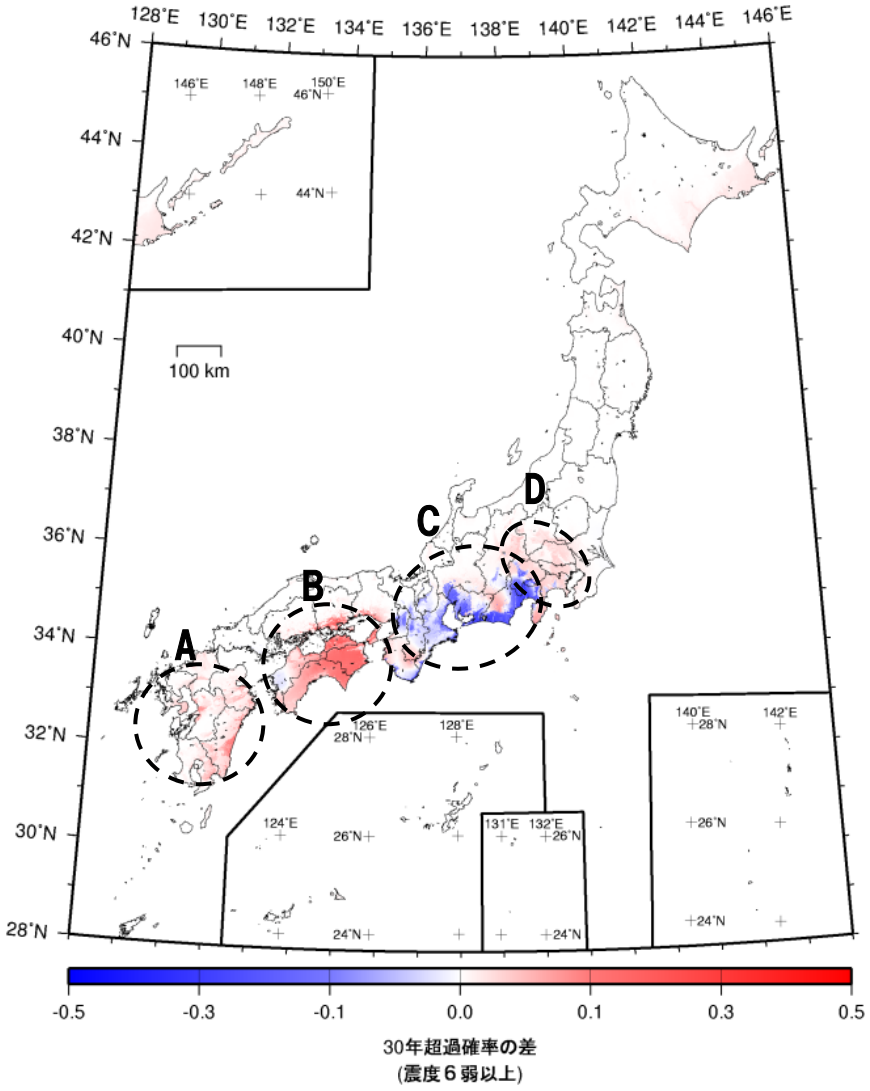
Source Area of Earthquakes

Two Successive Earthquakes



Difference (2013 model-2012 model)

Prob. that JMA seismic intensity is 6-Lower or greater in 30 years



A

- extended source area to Hyuga

B

- Probability of Nankai area
  62% → 66.5%

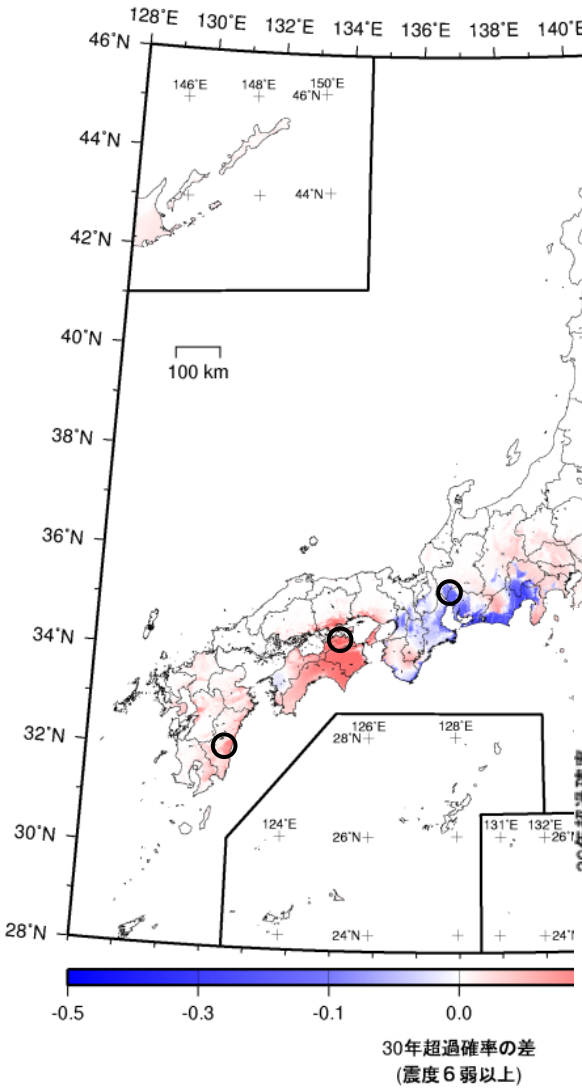
C

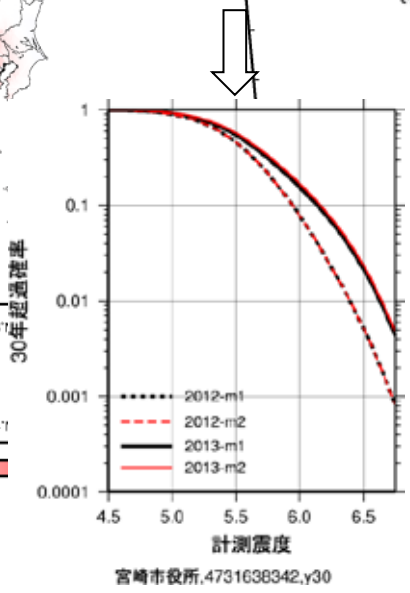
- Probability of Tonankai & Tokai
  Tonankai: 72% → 66.5%
  Tokai: 88% → 66.5%

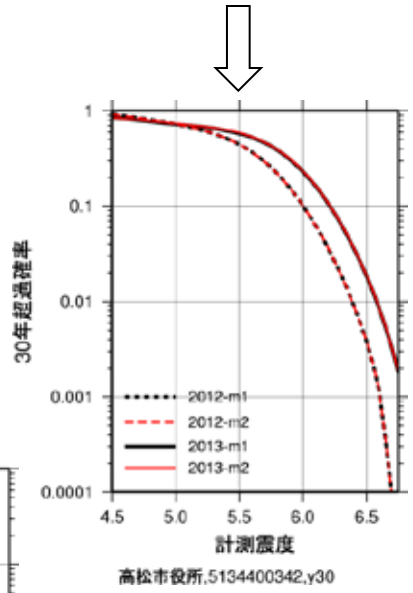
D

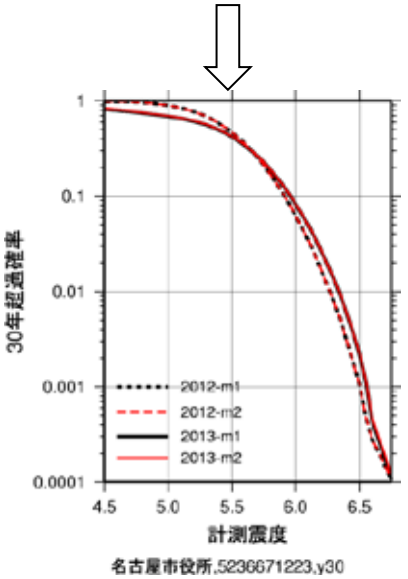
- larger earthquake
  (Tokai was 8.0 in old model)

Seismic Hazard Curves









Summary

1. Seismic activity models for earthquakes along Nankai Trough are presented
   - Old model based on Long-term evaluation 2001
   - New model based on Long-term evaluation 2013
2. Major points of model revision are expressed
   - Consideration of Up to M9.1 earthquake
   - Evaluation of occurrence probability of whole area, not for individual area
   - Variation of earthquakes
3. Seismic hazard maps based on both models are compared